# Environmental Considerations in Energy Development

## India Country Study

Draft Final Report

TATA ENERGY RESEARCH INSTITUTE
NEW DELHI

# Environmental Considerations in Energy Development

## India Country Study

Draft Final Report

Submitted to the

**Asian Development Bank**

December 1991

**Tata Energy Research Institute**
9 Jor Bagh, New Delhi - 110003
India

## EXECUTIVE SUMMARY

India is an oil importing developing country as well as an energy supply constrained economy whose environmental resources have degraded perceptibly in the last two decades. With rapidly increasing energy needs, it is imperative to meet development goals minimising undesirable social, economic and environmental consequences. Based on these considerations, this study has developed an optimal energy strategy for India to the year 2010.

Coal is India's major energy resource. As of 1990, proven and indicated coal reserves were estimated at 138 billion tonnes of which 27 billion tonnes was coking coal and the balance comprised non-coking coals, predominantly of inferior grade (high ash). The annual production was 209 million tonnes (MT). As of 1990, the proven and indicated balance recoverable reserves of crude oil and natural gas were only 757 MT and 686 billion cubic metres respectively. Currently, production of crude oil is around 31 MT per annum, meeting approximately 61% of the total requirement. Based on available data, the total 'economically' exploitable hydroelectric potential is 396.4 TWh of annual energy generation (75,400 MW at 60% load factor). Only one-fifth of this potential has been developed. Three-fourths of the population continues to depend on locally available biofuels that account for approximately 40% of the total energy consumption.

Growing industrialisation and urbanisation have contributed to a deterioration in air and water quality. Cities are heavily stressed, with total suspended particulate levels exceeding the ambient standards in several cities. In this context, Delhi, the capital of India, is now one of the world's most polluted cities. The discharge of industrial effluents and domestic sullage, mostly untreated, into rivers has resulted in water quality far below acceptable levels. Forest resources have declined over the years. Increasing population is not only adding to the demand for forest products but also for agricultural land which results in the clearing of forests. Based on 1987 imagery, only 19.47% of the country's geographical area was under forest cover, in comparison with the government's objectives of 33%.

Against this backdrop, the study explores three energy strategies to the year 2010. These are:

Business-as-usual (BAU) strategy
Based on current government thinking, this strategy forms the reference against which the alternative strategies are compared.

Strategy I
An environmentally superior strategy to the BAU, this is based on specific energy conservation measures for improving the efficiency of energy production, conversion and end-use along with energy demand management and technology changes.

Strategy II
Again an environmentally better strategy than the BAU, this is based on a greater utilisation of more environmentally benign energy forms, that includes the augmentation of power generating capacity by renewable energy technologies, and penetration of renewable energy forms and environmentally benign energy uses on the demand side.

The two strategies comprise mutually exclusive options and therefore cannot be compared directly. However, if both are found to be desirable, a combination strategy consisting of the components of both the strategies can be readily evaluated.

For each of the strategies, economic costs are evaluated. These include direct costs (equipment, labour, various inputs) valued in economic terms, and environmental and social costs across the energy cycle, i.e. from extraction to end-use. For evaluating environmental impacts over a region, an attempt is made to capture locational aspects, since a given level of discharge (emissions/effluents) will cause greater environmental damage in environmentally stressed areas than in relatively clean areas. This feature is incorporated for airsheds, where the airshed in a region is classified into three zones, based on the level of stress. Environmental costs are valued by indirect techniques using two approaches -- preventive expenditures and changes in productivity. However, data and methodological limitations made it difficult to place a monetary value on all impacts. Impacts valued are the emissions from thermal power plants of total suspended particulates, sulphur dioxide, oxides of nitrogen, and forest loss due to submergence from hydro projects and coal mining. Environmental impacts not valued include impacts from the transport and industrial sectors. These have been assessed using the multi-attribute assessment approach. Since only air emissions have been quantified for these sectors, the assessment is limited to 'airsheds'.

The exercise is conducted for two scenarios, characterized by GDP growth rates of 5% and 6%. The annualised costs (US$ million) in the year 2010 for the BAU strategy are 130,743 and 147,942; for strategy I are 109,630 and 125,594; and for strategy II are 130,228 and 147,428 for the 5 and 6 per cent GDP growth scenarios respectively. The multi-attribute assessment is done in terms of 'damage equivalent' emissions for air as a whole for the year 2010. The 'damage equivalent' emissions takes into account the damage potential of the three zones and the individual pollutants, and for the BAU are (in '000 tonnes) 18,215 and 25,815; strategy I are 8,450 and 9,486; and strategy II are 18,206 and 25,806 for the 5 and 6 per cent scenarios respectively. As can be seen both strategies are superior to the BAU, and therefore the combination strategy, which consists of energy conservation measures and a greater use of more environmentally benign energy forms is the best overall strategy. This is also seen from the results where the combination strategy has annualised costs (US$ million) of 109,115 and 125,079 and 'damage equivalent' emissions ('000 tonnes) of 8,441 and 9,477 for the 5 and 6 per cent growth scenarios respectively; both are the lowest in terms of total costs and unvalued air pollution.

A summary of the measures of the combined strategy are given below along with recommendations on institutional changes that would be required if this strategy is to be implemented.

**Energy conservation**

<u>Transport sector</u>

(1) Improved highway construction and maintenance. Not only does this option result in better energy efficiency but also in reduced pollution, reduced maintenance costs, etc. It is estimated that till the year 2010, this option would require US$ 8.7 billion. This level of investments and improvement in services can be brought about by involving the private sector on a contractual basis.

(2) Investments in urban rapid transit and metro facilities. The strategy considers metro systems for two mega and seven metropolitan cities needing an average investment of US$ 1.3 billion per metro system. This can be met realistically from external sources only. For quick and efficient implementation the build-operate-transfer (BOT) concept should be explored.

(3) Shifting of transport from roadways to railways. This would entail a major technological upgradation in the infrastructure and operations of the railways. This can only be brought about by major changes in the organisational set-up, by converting the zonal railways into separate public sector undertakings with greater autonomy. which would permit faster decision-making in attracting funds from the market for specific projects.

Industry
Conservation measures in three industries, namely iron and steel, cement, and chemicals and petrochemicals are considered in this study. Although energy conservation is economically attractive, the speed of implementation can be enhanced by dissemination of know-how and increased facilities from financial institutions to deal with energy conservation projects. Additionally, to increase co-generation facilities, legislation of the PURPA type would be required.

Public Utilities [illegible] and [illegible] Act

Domestic
Appliance efficiency improvements, specifically lighting and refrigeration are considered. Introduction and implementation of appliance standards, and improvement in the quality of power supply will enhance the usage of more energy efficient appliances.

Agriculture
Retrofitting of existing pump-sets and use of more energy efficient pump-sets are considered. Improvement of pump-sets can only be brought about by laying down efficiency standards. The heavy subsidy for irrigation pumping results in inefficient use of energy, and therefore the pricing of electricity needs to be addressed in this sector.

**Renewable energy technologies**

Wind
Wind farm capacity additions of 3000 MW is realisable till the year 2010 by the private sector and the utilities. Here again, legislation of the PURPA type would be required.

Small-hydel
Small-hydel capacity is also seen to be a viable option and a capacity of approximately 1500 MW is a realisable target till the year 2010. The standardization of the hydroelectrical equipment would insure better reliability and reduced costs.

Other technologies

These include biogas and solar cookers, the latter to be directed at semi-urban and peri-urban areas where fossil fuels are limited and fuelwood is commercialised.

**Alternative energy forms**

Compressed natural gas: A limited number of cars, buses and trucks using CNG is seen to be a viable option in several cities close to the existing gas pipeline network.

**Measures on the entire energy system**

Natural gas

The study projects a production of 53 bcm in the year 2010 which is completely absorbed in the BAU strategy. It would be useful to explore options for import of natural gas by pipeline from countries such as Bangladesh and Iran.

Oil

The study shows an import level of 54 MT per annum in year 2010 under the combination strategy. In order to close the gap by increasing production, the hydrocarbons industry must gradually move towards privatisation and develop policies for attracting foreign companies into oil exploration.

Coal

Results show coal production and usage to rise over 500 MT in the year 2010. This would require a rapid expansion of the coal transportation and distribution system. Results also show the economic viability of coal washeries. This needs to be vigorously pursued.

Power

In order to close the gap between electricity demand and supply (117 GW of additional capacity to be installed till 2010) early steps are essential to attract private sector participation. This can only be brought about by throwing open an entire region for generation, transmission and distribution, to be followed later in other regions.

Rural energy sector

Biofuels will continue to dominate the rural sector. Therefore, priority should be given to the enhancement of energy supply options such as afforestation and wastelands development along with the dissemination of biomass based efficient technologies. Since biofuels are locally available, rural energy programmes must have a decentralised approach.

**Contents**

## List of Tables

## Note

Classification of regions

North - Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab, Rajasthan, Uttar Pradesh, Chandigarh, Delhi.

West - Goa, Gujarat, Madhya Pradesh, Maharashtra, Dadra & Nagar Haveli, Daman & Diu.

South - Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Lakshwadeep, Pondicherry.

East - Bihar, Orissa, West Bengal, Andaman & Nicobar Islands.

North-East - Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura.

Exchange Rate (1990-91 prices)

1 US$ = 18 Rs

# CHAPTER 1

## Resource endowment

### 1.1 Environmental resources

#### 1.1.1 Physical features

Bounded by the Himalayas in the North, India stretches southwards and tapers off into the Indian Ocean with the Bay of Bengal in the East and the Arabian sea in the West. Lying between $8^{o}4'$ and $37^{o}6'$ North latitude and $68^{o}7'$ and $97^{o}25'$ East longitudes, the land mass which forms the subcontinent of India covers an area of 329 million hectares (mha) with a population of 843 million. It has a land frontier of 15,200 kilometres (km) and a coastline of 6083 km (7516.6 km including the islands).

Physiographically, India can be divided into seven divisions. These are the Northern Mountains, the Great Plains, the Central Highlands, the Peninsular Plateau, the East Coast Belt, the West Coast Belt and the Islands. The Himalayan range, 2500 km long and 250-400 km wide, with a mean elevation of 6000 metres in the central axial range, is the dominant geographical feature of India.

#### 1.1.2 Land use pattern

Out of the total geographical area of 329 mha, land use statistics are available for approximately 305 mha, constituting 93 per cent of the total area. The regionwise land utilisation in the country is indicated in Table 1.1. As can be seen from the table, over 41% (136.2 mha) of the total land area is under agriculture. Forests occupy an area of 20.3% (66.8 mha) and the balance 32 per cent of land is under different uses.

#### 1.1.3 Forest resources

Forest ecosystems in India, occupy an area of 66.858 mha, constituting over one-fifth (20.3%) of the total geographical area of the country; forestry being a major land use next only to agriculture. However, the area officially recorded as forest (recorded forest area), with or without tree cover, by the Forest Departments is of the order of 75.18 mha [22.8% of the total geographical area (GOI, 1988a & 1990b).

**Table 1.1.** Regionwise land utilisation in India (1987-88)

| | Land use | Area (Million ha) All India | Northern Region | Western Region | Southern Region | Eastern Region | North-Eastern Region |
|---|---|---|---|---|---|---|---|
| 1 | Forests | 66 858 | 11 489 | 21 409 | 12 096 | 10 287 | 11 577 |
| 2 | Area not available for cultivation | | | | | | |
| | (a) Area under non-agricultural uses | 20 809 | 5 156 | 4 559 | 5 536 | 4 232 | 1 326 |
| | (b) Barren and uncultivable land | 20 391 | 4 772 | 6 645 | 3.700 | 1 655 | 3 619 |
| 3 | Other uncultivated land (excluding fallows) | | | | | | |
| | (a) Permanent pastures and other grazing land | 11 848 | 3 542 | 5 019 | 2 153 | 0 860 | 0.274 |
| | (b) Land under miscellaneous tree crops and groves not included in net area sown | 3 535 | 0 691 | 0 339 | 0 782 | 1 084 | 0 639 |
| | (c) Cultivable wastelands | 15 626 | 7 429 | 4 709 | 1 728 | 1 030 | 0 730 |
| 4 | Fallow lands | | | | | | |
| | (a) Fallows other than current fallows | 11 134 | 3.903 | 2 216 | 2 747 | 1 492 | 0 776 |
| | (b) Current fallows | 18.471 | 7 081 | 2 337 | 5 545 | 3 056 | 0 452 |
| 5. | Agriculture (Net area sown) | 136 177 | 37 395 | 46 981 | 29 179 | 18 810 | 3 812 |
| 6 | Total reporting area | 304.849 | 81 458 | 94 214 | 63 466 | 42 506 | 23 205 |
| 7 | Area for which no returns exist | 23 877 | 19 614 | 0 932 | 0 164 | 0 153 | 3 014 |
| 8 | Total geographical area | 328 726 | 101 072 | 95 146 | 63 630 | 42.659 | 26 219 |

Source· Government of India (1990a)

Though the recorded forest area is 75.18 mha, estimates of <u>actual</u> forest cover (based on landsat imageries) put it as only 64.0134 mha (GOI, 1990b).

The regionwise distribution of recorded forest area, as well as figures for the actual forest cover as per the 1987 and 1989 assessments, are is shown in Table 1.2.

1.1.3.1 <u>Forest cover density</u>: Whereas the outer Himalayan forests and evergreen forests of the West Coast and North-east are fairly well stocked, large areas in Central India, Indo-

Gangetic plains, the coastal strips and other fertile valley systems are stocked either partially or entirely devoid of forests. Of the actual forest cover of over 64.01 mha, only 37.8470 mha are of adequate density (crown density 40% or more) while little over 25.74 mha are open forest with crown density varying from 10 to 40%. Over 0.42 mha constitute the mangroves. Thus, the effective forest cover (37.8470 mha-1989 assessment) in the country is limited to 11.51% of its geographical area, which is far below the figure of 33% envisaged in forest policies formulated in 1954 and 1988 (GOI, 1952 & 1988b).

**Table 1.2.** Forest land and forest cover in India

| Region | Recorded forest area (mha) | 1987 Assessment (1981-83 imagery) Actual forest cover (mha) | 1989 Assessment (1985-86 imagery) Actual forest cover (mha) |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| Northern | 12.9173 | 7.9110 | 8.2365 |
| Western | 23.9502 | 19.0257 | 19.0426 |
| Southern | 13.5956 | 11.1248 | 10.7875 |
| Eastern | 10.7808 | 9.8325 | 9.0089 |
| North-eastern | 13.9407 | 16.3101 | 16.9379 |
| All India | 75.1846 | 64.2041 | 64.0134 |

**Source:** GOI (1988a & 1990b)

The distribution of actual forest cover by various regions is shown in Table 1.3.

**Table 1.3.** Density of forest cover in various regions (mha)

| Density class | All India | Northern Region | Western Region | Southern Region | Eastern Region | North-eastern Region |
|---|---|---|---|---|---|---|
| Dense Forest | 37 8470 | 4 3697 | 12 4009 | 6 8355 | 5 0823 | 9 1586 |
| (Crown Density above 40%) | (11 51) | (4 32) | (13 03) | (10 74) | (11 91) | (34 93) |
| Open Forest | 25 7409 | 3 8668 | 6 5888 | 3 9068 | 3 5992 | 7 7793 |
| (Crown Density 10 to 40%) | (7 83) | (3 83) | (6 92) | (6 14) | (8 44) | (29 67) |
| Mangroves | 0 4255 | - | 0 0529 | 0 0452 | 0 3274 | - |
| | (0 13) | (0 00) | (0 06) | (0 07) | (0 77) | (0 00) |
| Total | 64 0134 | 8 2365 | 19 0426 | 10 7875 | 9 0089 | 16 9379 |
| | (19 47) | (8 15) | (20 01) | (16 95) | (21 12) | (64 60) |

Note· Figures in brackets indicate percentage of the geographical area of the region

Source. GOI (1990b)

1.1.3.2 Forest types: The extensive distribution of forest over the Indian subcontinent is accompanied by considerable diversity in their specific composition. Accordingly, the forests of the country have been divided into 16 type-groups (Champion and Seth, 1968) ranging from Tropical Wet Evergreen forests to Alpine types with the Tropical Deciduous types (both moist and dry) constituting the bulk (65.48%) of our forests. Nearly 8% of the actual forest cover consists of Tropical Wet Evergreens.

While Tropical Moist Deciduous forests occur in all the five regions, their incidence is high in the Western (over 8 mha) and North-eastern (over 5 mha) regions; the Tropical Dry Deciduous type being totally absent from the latter. There are no Wet Evergreen forests in the Northern region whereas they predominate in the Northeast. Mangroves are confined to the Western, Southern and Eastern regions. Subtropical, Temperate and Alpine types are spread in almost all the regions with a predominance in the Northern and North-eastern regions.

1.1.3.3 Growth and yield: The growing stock of the actual forest cover in Indian forests ranges from as low as 10 cubic metres ($m^3$) per ha in Rajasthan (Northern region) to as high as 277 $m^3$ in the coniferous forests of Kulu valley (Northern region). The average growing stock (65 $m^3$ per ha) compares poorly with the world average of 110 $m^3$ per ha (GOI, 1988a & 1990b). The total estimated growing stock of wood in the

country is placed at 4,196 million $m^3$ while the recorded production of wood (timber and fuelwood) during the last 10 years has varied from 26 million cubic metres (mcm) to 32 mcm; average annual production being of the order of 30 mcm. Unrecorded production in the form of dead/dying and annually fallen wood, which is removed as head-loads for domestic energy, is estimated at 22 mcm. Thus, the average annual production, within silviculturally permissible limits, is 52 mcm which may reasonably be assumed to be the net annual increment amounting to 1.24% of the total growing stock.

Considering the recorded forest area of the country (75.18 million ha), the average annual production of 52 mcm works out to 0.7 $m^3$ per ha which is much less than the world average of 2.1 $m^3$ per ha.

1.1.3.4 Man-made forests: While the existing naturally regenerated forests of the country continue to provide wood as a raw material, natural regeneration systems are not able to adequately cope with the rising demands of wood because of many limitations. Also, in a large proportion of the forests natural regeneration does not occur at all. This has led to the adoption of artificial regeneration practices, and large areas supporting an inferior natural crop have been replaced by pure and mixed plantations of species of high value. Plantations have so far (up to 1988-89) been raised over an area of 15.365 mha (Table 1.4).

**Table 1.4.** Area afforested (1951-1989) (mha)

| Period/Year | Total area afforested | Average annual area afforested |
|---|---|---|
| 1951-56 | 0.052 | 0.0104 |
| 1956-61 | 0.311 | 0.6222 |
| 1961-66 | 0.583 | 0.1166 |
| 1966-69 | 0.453 | 0.1510 |
| 1969-74 | 0.714 | 0.1428 |
| 1974-79 | 1.221 | 0.2442 |
| 1979-80 | 0.222 | 0.2220 |
| 1980-85 | 4.647 | 0.9294 |
| 1985-86 | 1.510 | 1.5100 |
| 1986-87 | 1.762 | 1.7620 |
| 1987-88 | 1.770 | 1.7700 |
| 1988-89 | 2.120 | 2.1200 |
| Total | 15.365 | |

**Source:** GOI (1989a & 1990c)

### 1.1.4 Protected areas and nature reserves

<u>Mangroves and wetlands</u>: According to field surveys, the total mangrove area, including the area permanently under water, is reckoned at about 674,000 ha (Table 1.5), the Eastern region having the largest area under mangroves (554,000 ha). India is rich in wetland resources that exhibit significant ecological diversity, primarily because of the climatic and topographical variability within the country. The regionwise distribution of mangroves and wetlands is shown in Table 1.5.

**Table 1.5.** Regionwise distribution of mangroves and wetlands

| Region | Area (ha) | |
|---|---|---|
| | Mangroves | Wetlands |
| Northern | - | 414,936 |
| Western | 79,000 | 1,025,489 |
| Southern | 41,000 | 1,565,307 |
| Eastern | 554,000 | 903,398 |
| North-eastern | - | 139,873 |
| All India | 674,000 | 4,050,137 |

**Source:** GOI (1987a & 1990d)

Fifteen mangrove areas and sixteen wetlands have been identified for conservation and scientific management (GOI, 1989b and 1990d). Thirteen potential sites, representing different biogeographical regions in India were identified for setting up of Biosphere Reserves as indicated in Table 1.6.

Table 1 6 Proposed biosphere reserves in India

| Region | Biosphere Reserves | | |
|---|---|---|---|
| | No | Area (ha) | Sites |
| Northern | 3 | 594,000 | Nanda Devi, Thar Desert, Uttarakhand |
| Western | 2 | 500,000 | Kanha, Rann of Kutch |
| Southern | 2 | 1,602,000 | Nilgiri, Gulf of Manas |
| Eastern | 2 | 137,500 | Sunderbans, North Andamans |
| North-eastern | 4 | 594,000 | Namdapha, Kaziranga, Manas, Nokrek |
| All India | 13 | 3,427,500 | |

Note Areas of Thar Desert (Northern Region), Kanha (Western Region) and Sunderbans (Eastern Region) are not given in the table as they are in the process of demarcation and delineation

Source GOI (1987b)

1.1.5 Water resources

Currently, the annual requirement for water is around 600 billion cubic metres (bcm), two-thirds of which is provided by surface waters and the rest by ground water. Annual requirements are expected to reach 750 bcm by the year 2000 and 1050 bcm by the year 2025.

1.1.5.1 Rivers: The river systems of India can be classified into four groups viz. (i) Himalayan rivers, (ii) Deccan rivers, (iii) coastal rivers, and (iv) rivers of the inland drainage basin. The Himalayan rivers are formed by melting of snows and glaciers and, therefore, have continuous flow throughout the year. During the monsoon months, the Himalayas receive very heavy rainfall and rivers swell, causing frequent floods. The Deccan rivers, on the other hand, are rainfed and therefore, fluctuate in volume. Many of these are non-perennial. The coastal streams, specially on the west coast, are short in length and have limited catchment areas. These rivers are of great importance as they contain as much as 14% of the country's water resources while draining only 3% of the land. The streams of inland drainage basin of Western Rajasthan are few and far between. They drain into salt lakes or get lost in sands with no outlet to the sea [Central Water Commission (CWC), 1988].

The annual precipitation is estimated at about 4000 bcm (including snowfall). The seasonal rainfall is of the order of 3000 bcm and the average annual natural flow is estimated to be 1880 bcm (CWC, 1988).

Rivers carry lesser volumes of water during the lean season, which affects irrigation through canals besides shrinking the capacity of the rivers to flush their beds in the plains. Coupled with lesser discharge is the problem of increased withdrawal of waters from the rivers; rivers thereby lose their natural cleansing capacity. With the discharge of industrial effluents and domestic sullage, the quality of water in these rivers has deteriorated so much that the water is unfit for human consumption. As much as 70% of water sources are polluted by human and industrial wastes, most of which can be traced to the discharge of untreated human waste into the natural drainage system. Of the 3119 towns and cities in the country, only 209 have partial and just eight have full sewage treatment facilities (Chaphekar, 1991). Polluted water is responsible for two-thirds of all illnesses and at times the incidence of typhoid, cholera, malaria, diarrhoea, and dysentery reaches epidemic proportions.

Although industrial wastes, discharged into water bodies, are just a quarter of the community wastes, treatment of polluted water is more complex and expensive. This is because of the qualitative differences in pollution according to the industries involved, and due to non-degradability of many of the effluents. Of the over 4000 water-polluting large industrial units, only about half have installed pollution control equipment. Many small units have not even begun to think in terms of controlling pollution.

**Table 1.7.** Primary water quality criteria

| Designated Best Use | Class of Water | Criteria |
|---|---|---|
| Drinking water source without conventional treatment but after disinfection | A | 1. Total Coliform Organisms MPN/100ml shall be 50 or less.<br>2. pH between 6.5 and 8.5<br>3. Dissolved Oxygen 6 mg/1 or more<br>4. Biochemical Oxygen Demand 5 days 20$^{o}$C, 2mg/1 or less |
| Outdoor bathing (Organised) | B | 1. Total Coliform Organisms MPN/100ml shall be 500 or less.<br>2. pH between 6.5 and 8.5<br>3. Dissolved Oxygen 5mg/1 or more<br>4. Biochemical Oxygen Demand 5 days 20$^{o}$C, 3 mg/1 or less |
| Drinking water source | C | 1. Total Coliform Organisms MPN/100ml shall be 5000 or less.<br>2. pH between 6.5 to 8.5<br>3. Dissolved Oxygen 4 mg/1 or more<br>4. Biochemical Oxygen Demand 5 days 20$^{o}$C, 3mg/1 or less |
| Propagation of wildlife, fisheries | D | 1. pH between 6.5 and 8.5<br>2. Dissolved Oxygen 4mg/1 or more<br>3. Free Ammonia (as N) 1.2 mg/1 or less. |
| Irrigation, Industrial cooling, Controlled Waste | E | 1. pH between 6.0 and 8.5<br>2. Electrical Conductivity at 25$^{o}$C micro mhos/cm Max 2250.<br>3. Sodium Absorption Ratio Max 26.<br>4. Boron, Max 2 mg/1 |

Table 1.7 shows the classification of water in terms of designated best use and primary water quality criteria.

Using this classification, Table 1.8 gives an assessment of water quality for the major rivers in India. As can be seen, the most critical parameters are coliforms and Biochemical Oxygen Demand.

**Table 1.8.** Water quality of major rivers in India

| River | Length (km) | Level: Desired | Level: Existing (most places) | Critical parameters |
|---|---|---|---|---|
| Baitarani | 355 | B | Below C | BOD |
| Brahmani | 799 | C | Below C | BOD |
| Brahmaputra | 720 | C | na | na |
| Cauvery | 800 | C | C | - |
| Ganga | 2525 | B | na | na |
| Godavari | 1465 | B,C | C, below C | BOD |
| Beas | 460 | A,C | C, below C | Coliforms, DO |
| Ravi | 370 | A,C | C, below C | Coliforms |
| Sutlej | - | A,C | C, below C | Coliforms, BOD, DO |
| Krishna | 1401 | C | C, below C | BOD |
| Mahanadi | 857 | C | na | na |
| Mahi | 533 | A,C | C, below C | Coliforms, BOD |
| Narmada | 1312 | A,B,C | C, below C | Coliforms, BOD |
| Pennar | 597 | C | C | BOD |
| Sabarmati | 371 | A,E | C, below C | Coliforms |
| Subarnarekha | 395 | C | below C | Coliforms, BOD, DO |
| Tapi | 724 | A,C | C, below C | Coliforms, BOD |
| Yamuna | 1376 | B,C | below C | Coliforms, BOD, DO |

1.5.2 <u>Ground water</u>: There are three important formations of soil and rock in India, which have a bearing on the yield of ground water. A very large portion of the country (nearly 120 mha) consists of consolidated hard rock formation. The yield in such areas is low. In the semi-consolidated formation which covers about 5 mha, sedimentary rocks such as sandstones, limestones and conglomerates occur. The yield in

these area is moderate. These formations occur particularly in Rajasthan, Gujarat and Tamil Nadu. There are large areas of unconsolidated formations consisting mainly of sand, gravel, boulders, laterites, soil and clay. These areas include valleys like Kashmir, the Indus basin, Ganga-Brahmaputra Meghna basin and coastal tracts. These areas yield substantial quantities of ground water.

The Central Ground Water Board (CGWB) has estimated the annual utilisable ground water resources at about 418 bcm while the present annual utilisation is about 100 bcm. This is approximately 24% of the total utilisable resources.

### 1.1.6 Air quality

At the regional level, urban and industrial air pollution is a serious problem in the country. Since most of the growth in population will occur in urban areas, urban air quality will become increasingly crucial to human health. Household pollution, owing to combustion of low grade fuels in traditional devices, in most of the rural areas and in the low income groups of urban areas, is another major concern.

The quality of air can be described meaningfully only with the help of ambient air quality standards. The Central Pollution Control Board (CPCB) laid down the standards in 1982, which are currently being revised. The new proposed standards are given in Table 1.9.

**Table 1.9.** Proposed national ambient air quality standards

| Pollutant | Averaging Time | Concentration ($ug/m^3$) | |
|---|---|---|---|
| | | General Area | Sensitive Area |
| $SO_2$ | Annual Avg* | 80 (0.03 ppm) | 30 |
| | 24 h | 130 (0.05 ppm) | 30 |
| | 1 h | 655 (0.25 ppm) | |
| $NO_2$ | Annual Avg* | 100 (0.053 ppm) | 30 |
| | 24 h | 200 (0.106 ppm) | 30 |
| | 1 h | 470 (0.25 ppm) | |
| TSP | Annual Avg* | 200 (400 $ug/m^3$)# | 100 (200 $ug/m^3$) |
| | 24 h | 400 (800 $ug/m^3$)# | 200 (400 $ug/m^3$) |

* Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform intervals.
\# Not more than 2% of the total number of observations in a year should exceed the figures presented within the brackets for TSP.

**Source :** Central Pollution Control Board (1991)

Air Quality at specific locations : Based on the data for 33 cities of India, the following findings were made:

(i) Howrah, Ahmedabad, Annapara and Bhilai have the ten most polluted industrial areas.

(ii) Surat, Dehra Dun, Delhi, Pune and Bangalore have the ten most polluted commercial areas.

(iii) Delhi, Kota, Agra, Bhilai, Faridabad have the ten most polluted residential areas.

(iv) TSP exceeded the standards at almost all the locations.

(v) Three out of the four locations in Howrah were amongst the top 10 locations that had high concentrations of all the three pollutants. All the three pollutants exceeded the proposed standards.

(vi) Sulphur dioxide concentrations at all but one location were within the stipulated standards.

(vii) For nitrogen dioxide, the annual mean values exceeded the proposed air quality standard at Kota and Howrah. The annual mean values for 1989 were higher than the corresponding values for 1988 at almost all the locations at Kota and Madras.

(viii) In Howrah, the sulphur dioxide levels exceededthe standards 11-24% of the time.

(ix) Again, in Howrah and Dehra Dun, TSP levels exceeded the standards more than 75% of the time.

(x) The nitrogen dioxide standards were exceeded than those most number of times in Kota (15-20%).

(xi) The mean concentration of TSP in the three classified areas is significantly different, implying thereby that background concentration of TSP in these regions has a significant impact on the measured TSP values.

Clearly, these data suggest that Howrah, Kota, Madras and Baroda have a serious air quality problem. However, very strangely, though Delhi recorded high annual averages, it was absent from the list of the cities where standards were violated for a significant fraction of the time. It is likely that uncertainty in data led to such a result. Data for Bombay have not been collected by CPCB. If we were to consider data gathered by the Municipal Corporation of Greater Bombay, then it is seen that Bombay has the highest levels of nitrogen dioxide in commercial areas.

Comparison with other countries : With regard to $SO_2$, the major Indian cities have an average air quality. Countries like China, Brazil, Mexico, Iran, South Korea, France, Italy

and Yugoslavia have cities with higher concentrations of $SO_2$. But in the context of TSP, Indian cities fare the worst, with Chinese cities having the second highest concentrations (WRI, 1991). Of course, one must keep in mind that background natural dust in semi-arid areas is high. Monitoring of fine particulate matter will resolve this question. The high TSP values may also indicate increasing use of diesel for transport.

## 1.2 **Energy resources and reserves**

### 1.2.1 Coal and Lignite

The quantity of coal reserves available in the country is assessed on a continuous basis regionally by the Geological Survey of India (GSI) through regional mapping and exploratory drilling. Detailed drilling is carried out by other agencies. Since the nationalisation of the coal industry in the early 1970s, the tempo of exploration has increased significantly, and detailed drilling is done by the Central Mine Planning and Design Institute Ltd. (CMPDIL), the Mineral Exploration Corporation (MEC) and the respective State Governments.

Coal is the mainstay of India's energy economy, and is expected to remain so in the foreseeable future. The demand for coal grew at about 8% per annum in the 1980s, and the annual production in 1989/90 crossed the 200 million tonnes (MT) mark.

Total coal reserves are estimated at about 186 billion tonnes (Table 1.10). The major workable deposits of coal occur in a great succession of fresh water sediments, commonly known as "Gondwana" coals of permian age (215 million years ago). These reserves constitute nearly 99.5% of the total coal resources of the country. There are small deposits of coal of tertiary age (25-60 million years ago) in the North-eastern states, which contribute the balance 0.5% of the total resources. In addition, there are lignite deposits of the tertiary age in Tamil Nadu, Gujarat, Rajasthan and Kashmir. Differences in the geological age are accompanied by differences in the chemical composition; the Gondwana coals being largely bituminous, and the tertiary coals largely lignitic and lignite. The bulk of the present economically viable coal reserves is confined to a 14369 sq. km area, distributed amongst 57 peninsular Gondwana coalfields, and 180 sq. km (14 tertiary coalfields) of North-eastern India. Major coal deposits are in Bihar, West Bengal

and Orissa (Eastern Region), Madhya Pradesh (Western Region) and Andhra Pradesh (Southern Region).

The salient features of the reserves are as follows:

(i) reserves under the proven category are only 30% of the total reserves;

(ii) about 63% of the total reserves occur at depths of 300 metres or less, and 27% occur in the depth range of 300 metres to 600 metres. Only about 10% of the reserves occur beyond 600 metres depth, and are mainly located in deep coal basins like Raniganj, Jharia, South Karanpura, East/West Bokaro and Godavari coalfields;

(iii) prime coking coal reserves are restricted to Jharia coalfields, and are less than 3% of the total reserves. However, coal deposits that are close to prime coking coal in characteristics have been located in East/West Bokaro and parts of Sohagpur coalfields;

(iv) reserves of medium coking and semi-coking coals constitute about 13% of the total reserves;

(v) reserves of superior non-coking coals (grades A, B, and C) are limited (about 12% of total reserves), with the major deposits lying in the Raniganj coalfields. Sizeable reserves are also available in Talcher, Korba, South Karanpura, Chirimiri and a few other coalfields. Substantial reserves of deep-seated superior quality coal have now been identified by regional exploration in Birbhum and Domra-Panagarh areas of West Bengal; and

(vi) the bulk of the coal reserves in the country (73%) are inferior grade non-coking coals, occurring largely in thick interbanded seams and located in coalfields like Singrauli, Ib Valley, Talcher, North Karanpura, Rajmahal, Korba, Wardha and so forth. Recoverable reserves are only 56.5 billion tonnes. Of these, less than 9 billion tonnes are coking coals (prime coking coal reserves being about 1.2 billion tonnes; the rest being medium and semi-coking coals). The remaining 47.5 billion tonnes are non-coking coals - predominantly of an inferior grade. Reserves of grade A and B non-coking coals are less than 1.4 billion tonnes.

Table 1.10. Coal reserves as on 1 January 1990 (billion tonnes)

| Type of Coal | Proved | Indicated | Inferred | Total |
|---|---|---|---|---|
| Coking Coal | | | | |
| Prime | 4 23 | 1 07 | - | 5 30 |
| Medium | 9 37 | 10 99 | 1 23 | 21 59 |
| Semi | 0 55 | 0 91 | 0 62 | 2 08 |
| Sub-total | 14 15 | 12 97 | 1 85 | 28 97 |
| Non-Coking Coal | 42 14 | 68 41 | 46 52 | 157 07 |
| Total | 56 29 | 81 38 | 48 37 | 186 04 |

Source "Personal Communications", Geological Survey of India, 1991

The actual production potential is dependent not on "geological" reserves, but on "mineable" and "recoverable" reserves. according to Government of India (1988c), in which the coal reserves data are analyzed, about 99.2 billion tonnes of mineable reserves are available for future projectisation. A break-up of this estimate of mineable reserves under broad depth and quality classes is given in Table 1.11.

Table 1 11 Mineable and recoverable reserves (billion tonnes)

| Type | Depth 0-300 m MR* | 0-300 m RR# | > 300 m MR | > 300 m RR | Total MR | Total RR |
|---|---|---|---|---|---|---|
| Coking Coal | | | | | | |
| i) Prime | 0 40 | 0.22 | 1 90 | 0 96 | 2 30 | 1 18 |
| ii) Medium | 6 98 | 4 01 | 6 64 | 3 10 | 13 62 | 7 11 |
| iii) Semi | 0 38 | 0 24 | 0 58 | 0 37 | 0 96 | 0 61 |
| Sub Total | 7.76 | 4.47 | 9 12 | 4 43 | 16 88 | 8 90 |
| Non-Coking Coal | | | | | | |
| i) Superior | 10 95 | 6 76 | 5 24 | 2 65 | 16 19 | 9 41 |
| a) A & B | | | | | 2 75 | 1 38 |
| b) C & D | | | | | 13 44 | 8 03 |
| ii) Inferior | 47 68 | 29 87 | 18 14 | 8 30 | 66 09 | 38 77 |
| Sub Total | 58 63 | 36 63 | 23 65 | 10 95 | 82 28 | 47 58 |
| | 66 39 | 41 10 | 32 77 | 15.38 | 99 16 | 56 48 |

Source: GOI (1988c)

* MR Mineable Reserves, # RR · Recoverable Reserves

The mineable reserves are derived on the following basis: (i) The certainty equivalent of proven, indicated and inferred reserves (0.9 for proven, 0.65 for indicated and 0.3 for inferred); and (ii) blockage of coal reserves for different geophysical conditions such as underground fires, water, township, railways, roads, etc.

The recoverable reserves based on certain recovery factors for various coalfields and depth-thickness combinations have been worked out by the Planning Commission (1988), and are summarized in Table 1.11. The table shows that 36.6 billion tonnes of non-coking coal and 4.47 billion tonnes of coking coals are mineable from depths of less than 300 metres, using open-cast mining methods.

Compared to coal, lignite reserves are rather small, the proven and inferred reserves together being 8.5 billion tonnes (Table 1.12). Lignite deposits occur mostly in Neyveli (Tamil Nadu in the Southern Region), where the reserves are about 6.55 billion tonnes, of which about 2.1 billion tonnes are proven. These deposits account for about 80% of total proven lignite reserves in the country, and are already being used for power generation in a significant way. Further expansion is in progress. Some smaller lignite deposits in Gujarat are also being developed for power generation.

**Table 1.12.** Lignite -- proven and inferred reserves (MT)

| State | Region | Proven | Inferred | Total |
|---|---|---|---|---|
| Tamil Nadu | South | 2100 | 4450 | 6550 |
| Pondicherry | South | - | 480 | 480 |
| Rajasthan | North | 385 | 640 | 1025 |
| Gujarat | West | 94 | 247 | 341 |
| Jammu & Kashmir | North | 7 | 83 | 90 |
| All India | | 2586 | 5900 | 8486 |

.2.2 Oil and Natural Gas

The total area of sedimentary basins in India is about 1.72 million square km (mkm), of which 1.4 mkm are on land, and the remaining offshore, within the 200 metres isobath line. There are 26 sedimentary basins, of which 13 are of interest geologically. As per the latest estimates available from the GOI's Department of Petroleum and Natural Gas (Personal Communications), the total prognosticated hydrocarbon resources are about 21 billion tonnes of oil and oil equivalent of gas (Table 1.13). Approximately 11.3 billion tonnes are in Category I basins while the rest are in Category II and III basins.* About 62% of total

---

* Category I basins: proven petroliferous basins where commercial production has already begun; Category II basins: sedimentary basins with known occurrence of hydrocarbons, but from which no commercial production has yet been obtained; and Category III basins: sedimentary basins in which significant evidence of hydro- carbons has not yet been found, but which, on general geological grounds, are considered possible.

prognosticated resources are in offshore areas, and over half of total theoretical resources are expected to be in the form of natural gas.

However, as of 1990, the proven and indicated balance recoverable reserves of crude oil and natural gas were only 757 million tonnes and 686 billion cubic metre (bcm) respectively. These reserves are located mainly along the West Coast between the Gulf of Cambay and Bombay and in the North-eastern region in Upper Assam, and may be disaggregated as follows: (i) Bombay High offshore basin: 450 million tonnes of crude oil and 457 bcm of gas; (ii) Cambay basin: 162 million tonnes of crude oil and 93 bcm of natural gas; (iii) Upper Assam basin: 145 million tonnes of crude oil and 135 bcm of gas; and (iv) Rajasthan: 1.04 bcm of gas. A part of the natural gas occurs as associated gas, the production of which is related to oil production.

**Table 1.13.** Prognosticated hydrocarbon resources

| | Prognosticated Resources (mtoe) | Gas-Oil Ratio (cu.m/t) |
|---|---|---|
| **Onshore** | 7772 | |
| Cambay | 1650 | 249.9 |
| Upper Assam | 2280 | 476.3 |
| K. Godavari | 217 | 2796.5 |
| Cauvery | 166 | 835.1 |
| Bengal | 326 | 835.1 |
| Assam-Arakan | 2110 | 820.6 |
| K. Saurashtra | 263 | 835.1 |
| HF & G. Valley | 370 | 835.1 |
| Rajasthan | 340 | 4784.7 |
| Mahanadi | 50 | 835.1 |
| | | |
| **Offshore** | 12773 | |
| K. Godavari | 543 | 549.8 |
| Cauvery | 374 | 829.1 |
| Bengal | 634 | 1813.5 |
| K. Saurashtra | 497 | 436.9 |
| Kerala-Konkan | 1630 | 2919.2 |
| Mahanadi | 1240 | 1820.3 |
| Andaman | 465 | 1820.3 |
| Bombay High | 7390 | 455.8 |

**Source:** "Personal Communications", Department of Petroleum and Natural Gas, 1991.

While most of the exploration until 1979 was concentrated in Category I basins, exploration in category II and III basins accelerated substantially in the 1980s. In the Seventh Five-Year Plan period (1985/86 to 1989/90), nearly half of the exploratory effort was in Category II and III basins. This trend of an increasing exploratory effort in category II and III basins is likely to continue over the foreseeable future, as geophysical and surface surveys conducted there so far have shown structures that are favourable for hydrocarbon accumulation. Moreover, as the category I basins have been explored relatively intensively, it is expected that most new discoveries there would be small deposits in stratigraphic traps, which may be difficult to exploit.

Efforts are being made to improve recovery factors from the producing oil fields. The necessary R & D efforts are under-way, and pilot projects using various enhanced oil recovery (EOR) techniques have been initiated. In particular, thermal methods (such as in-situ combustion and steam flooding) and chemical injection methods (such as polymer/micellar-polymer/caustic flooding) of EOR have been tried. Preliminary results indicate over 10% of additional recovery in all pilot tests.

### 1.2.3 Hydropower

According to available data, India's total economically exploitable hydroelectric potential is 396.4 TWh of annual energy generation, or about 75,400 MW at 60% load factor. Approximately one-fifth of this potential has been developed so far. Most of the unexploited potential is concentrated in the Northern and North-eastern regions (about 48,000 MW). Low demand for electric power impedes development of hydroelectric projects in the Northeast. Over 60% of the potential in the Southern Region has been developed so far.

Hydropower development is now being increasingly integrated into optimal river valley development programmes. Several multi-purpose projects with hydroelectric power as one of the components (the other being surface irrigation) have now been developed. The first such project was in the Cauvery basin at Mettur in the Southern Region.

While the advantages of hydropower are well recognized, the exploitation of hydropower resources has been constrained by several factors. These include differences in inter-state priorities, long gestation periods, financial constraints, and problems of land submergence and resettlement of affected population.

The fact that hydropower development has not kept pace with the demand for power is a cause for concern. Given the Indian energy situation, it is necessary to restore the confidence in hydro development, ensure availability of modern technology for investigation and construction of hydro projects, rationally view the concerns of environmentalists and carefully select some major sites for early development.

One possibility is small hydropower development. No reliable estimates of the potential for small hydro are available. Some idea of the immense potential can be obtained from the estimates made by the Rural Electrification Corporation (REC) based on surveys in the mid 1980s for small hydro power generation potential on existing irrigation systems in the country. Over a thousand sites were identified on existing irrigation dams, canal drops, diversion weirs, etc. and the potential was estimated at over 5,000 MW. The REC survey highlighted the concentration of projects in the southern states of Andhra Pradesh, Karnataka and Tamil Nadu where the potential was placed at 2000 Gwh of energy annually at 500 sites.

### 1.2.4 Nuclear energy

The Department of Atomic Energy estimates the uranium resources to be about 70,000 tonnes, the thermal reactor equivalent of about 1.9 billion tonnes of coal. India also has thorium deposits, estimated at 360,000 tonnes, that can support a large nuclear programme based on breeder reactor technology. Thorium is seen as the single most important energy resource in the long term.

### 1.2.5 Biomass fuels

Unlike commercial energy sources, biofuels are by-products of livestock, agricultural and forestry resources which play different primary roles in the economy. These fuels make a significant contribution in meeting energy demands in the domestic sector.

1.2.5.1 Fuelwood: The current production of fuelwood from forests, as estimated by the Forest Survey of India, is placed at 52 million $m^3$ (36 million tonnes) [GOI, 1989a]. This includes the unrecorded production of fuelwood in the form of dead/dying and seasonally fallen wood which is collected from the forests as head-loads by the villagers living near the forests. This, however, is on the lower side of estimated sustainable yields which vary between 36-43 MT/year. The optimistic regionwise sustainable firewood yield is summarised in Table 1.14. The estimates from the so called

"unrecorded sources" which include supply of fuelwood from private lands, gardens, trees around houses, shifting cultivation areas and the like show even a higher level of disparity. These estimates are in the range of 30-80 MT/year [GOI (1989a) and Advisory Board on Energy (1985)]. Thus, the total availability of fuelwood, at present is in the range of 66-123 MT/year including both recorded and unrecorded sources.

**Table 1.14.** Regional biomass availability (1989) (MT)

| Region | Sustainable firewood yield | Non-fodder crop residues | Dung fuel (wet) |
|---|---|---|---|
| East | 5.555 | 18.514 | 82.754 |
| North | 4.948 | 49.662 | 99.020 |
| North-East | 12.109 | 3.004 | 0.003 |
| South | 7.590 | 37.393 | 13.577 |
| West | 12.334 | 32.476 | 49.244 |
| **Total** | **42.536** | 141.049 | 244.598 |

No significant increase is expected in the supply of fuelwood in the coming decade from forest areas, as the resource base is shrinking due to a population increase and other developmental activities. Additionally, green felling from forests has been stopped in many states on environmental considerations. The supply of fuelwood from forests would, therefore, remain static at the present levels, if it does not decrease. The availability from non-forest sources beyond AD 2000 would essentially depend on the social forestry and afforestation work undertaken in the next decade.

1.2.5.2 Crop residues: Crop residues are those plant materials that are left in the field or in agro-based industries after extracting the main crop produce. These materials are available in the form of straws, stalks, husk, leaves, fibrous material, roots and other parts of the plant material. No reliable data are available with regard to the quantity of crop residues used either as fodder or fuel. A rough estimate for non-fodder crop residues for the year 1989 is around 140 MT/year, out of which 65-70 MT/year is already in use in the sugar industry. Regionwise estimates are given in Table 1.14.

1.2.5.3 Dung-cakes: It is estimated that the total dung fuel available for 1989 was about 245 MT (wet basis). It is

expected that the bovine population will not increase beyond the 1990 estimates without affecting its quality. Therefore, dung production is expected to stabilise in the future. Regionwise details are shown in Table 1.14.

### 1.2.6 Wind energy

A recent exercise on wind mapping and wind monitoring of potential regions in India has identified several locations along the western/southern coasts and inland areas where wind power generation would be economical. Some sites identified in Tamil Nadu are comparable with the best windfarm sites in the world. The potential for wind power generation on the basis of land availability, wind speeds, and economic viability have been computed to be more than 150000 MW. However, the peak generating capacity of conventional units and the availability of the grid are some of the limiting factors and the technically realisable potential has been estimated to be 40000 MW.

### 1.2.7 Solar energy

Radiation climatology of the Indian subcontinent is fairly well documented. Computed radiation data at scales useful for analysing solar energy utilisation indicate that the country as a whole receives about 2000 kWh/$m^2$/year with the highest amount in western India and the lowest in the east and north east (about 1700 kWh/$m^2$/year). Solar energy can be used for low grade thermal applications (solar cooking, hot water systems, etc.) as well as for high temperature applications such as solar thermal power generation.

### 1.2.8 Energy trade options in the Indian subcontinent

The two main energy trade options are electricity (hydropower) and natural gas. Nepal and Bhutan have large hydropower potential estimated at 83,000 MW and 20,000 MW respectively, with an exploitable potential of 44,500 MW and 20,000 MW respectively. At present, Nepal has an installed capacity of 232 MW and Bhutan 355 MW, 95% of which is currently utilised by India. Major schemes being studied between India and Nepal include Karnali (3,000-6,000 MW) and Pancheswar (2,000-3,000 MW).

The other energy option is the import of natural gas from Bangladesh, which has total reserves of 1050 bcm (of which 75% are recoverable) against a present annual consumption level of approximately 4 bcm.

CHAPTER
2

# Energy demand

## 2.1 Trends in energy demand

India is highly dependent on fossil fuels for meeting its commercial energy requirements. It has moved from being largely a biomass based economy at the time of independence to a 60 per cent dependence on commercial energy forms. Coal and petroleum products form the main energy sources and the share of natural gas is increasing quite rapidly.

A broad sectoral analysis of energy consumption reveals that the fastest growing sectors, in terms of energy consumption, are the agricultural and the residential sectors wherein consumption has grown at 11.42 per cent and 9.36 per cent respectively during the period 1972-73 to 1988-89 (Table 2.1). In terms of absolute energy consumption, the industrial sector accounts for a major part of energy consumption followed by the transport sector. Utilization of various energy forms for non-energy purposes (naphtha as feedstock, lubes and greases and natural gas used in industry) has also increased rapidly, at about 7 per cent per annum, during the same time period.

An analysis of energy demand by fuel reveals that the share of industry in electricity consumption has declined considerably over the period 1980-81 to 1988-89 while that of the agricultural and residential sectors has increased quite significantly. While residential electricity demands have gone up from 11 per cent to 14 per cent of total electricity demands, the issue of significance here is that these demands are found to coincide with the peak demand. In the case of the agricultural sector the increase in demand is largely due to the Government policy of rural electrification and thereby energisation of pump-sets. The electricity boards however adopt a number of measures to ensure that rural pump-sets do not operate during peak demand periods.

Table 2 1 Trends in availability and consumption of commercial energy 1972-73 to 1988-89

(million tonnes of oil equivalent)

| Year | Gross availability | Conversion losses | Net availability/ consumption (col4-9) | Agriculture | Industry | Transport | Residential | Other energy uses | Non energy uses |
|---|---|---|---|---|---|---|---|---|---|
| 1972-73 | 68 483 | 14.396 | 54 087 | 0 78 | 29 717 | 13 579 | 4 533 | 1 542 | 3 936 |
| | | | (100 0) | (1 4) | (54 9) | (25 1) | (8 4) | (2 9) | (7 3) |
| 1980-81 | 92 623 | 23.859 | 68 764 | 1 625 | 36 861 | 17 443 | 5 637 | 1 901 | 5 297 |
| | | | (100 0) | (2 3) | (53 6) | (25 4) | (8 2) | (2 8) | (7 7) |
| 1982-83 | 109 023 | 28 552 | 80 471 | 1 861 | 44 225 | 18 758 | 6 82 | 2 127 | 6 68 |
| | | | (100 0) | (2 3) | (55.0) | (23 3) | (8 5) | (2 6) | (8 3) |
| 1984-85 | 121 51 | 34.997 | 86 513 | 2 131 | 46 595 | 20 309 | 8 038 | 2 341 | 7 099 |
| | | | (100 0) | (2 5) | (53 8) | (23 5) | (9 3) | (2 7) | (8 5) |
| 1986-87 | 141 187 | 40 927 | 100 26 | 2 807 | 53 423 | 22 789 | 9 532 | 2 677 | 9 032 |
| | | | (100 0) | (2 8) | (53 3) | (22 7) | (9 5) | (2 7) | (9 0) |
| 1988-89 | 163 606 | 52 621 | 110 985 | 3 861 | 56 214 | 26 055 | 11 532 | 3 684 | 9 639 |
| | | | (100 0) | (3 5) | (50 6) | (23 5) | (10 4) | (3 3) | (8 7) |

Source Compiled from energy balances in TERI, 1990

Note Figures in brackets give % shares

The share of the transport sector in oil consumption has been increasing due to the absence of an alternative transportation fuel both in the road sector as well as in the railways. Electrification of rail routes is limited by the density of traffic required to make this an economically efficient option. Similarly, in the domestic sector the only commercial energy alternative to cooking fuels is petroleum based products. Both these factors have contributed to the disproportionately large demand for middle distillate (kerosene and diesel) in India.

In the case of coal close to 61% of coal consumption in 1990-91 was accounted for by the power sector and 35% by industrial sector. Coal consumption by railways is declining due to a conscious policy adopted by the Government of India to phase out highly inefficient steam locomotives and replacing them with diesel and electric traction.

Natural gas consumption in the country is still extremely low with well over 40 per cent of natural gas produced being flared even as of today. Industry accounts for close to 98 per cent of the gas that is consumed, largely in fertilizer and petrochemicals industries (non-energy purposes) and for power generation purposes.

Given the past growth and pattern of energy demand the present study attempts to provide snapshot pictures of future energy demands. To do so energy demands have been disaggregated regionally and projected into the future using an end-use approach. Sectoral growths are first estimated and then useful useful energy consumption norms applied to them. Next, these useful energy demands are distributed over the various fuel alternatives taking into account efficiencies of utilization, availability of various fuel types and present distribution patterns. Demands have been based on two scenarios: (i) an all India GDP growth rate of 5 per cent per annum and a population growth of 2.01% till 1999-2000 and 1.81% thereafter (ii) a 6 per cent GDP growth accompanied by a population growth which linearly declines from 1.81% in the first five year period 1990-91 to 1994-95 to 1.42% during 2004-05 to 2009-10.

## 2.2 Methodology for sectoral energy demand projections

### 2.2.1 Agriculture

The total energy consumption in the agricultural sector increased rapidly over the period 1971-88. The agricultural sector has been under tremendous pressure to increase productivity not only due to an increasing population in the rural areas, but also due to an increasing non-agricultural based population.

Land area available for agricultural purposes has been more or less stagnant from the early 1970s. However, there has been an increase in gross cropped area due to the increased intensity of land use through double cropping and multiple-cropping. A large part of this increase in gross cropped area has been possible due to the introduction of energy intensive high yielding varieties (HYV) of crops which have a high energy input intensity since the late 1960s. The introduction of the HYVs and the high incidence of droughts since the mid-1960s have contributed to the increased use of energy in the agricultural sector.

While the estimates of diesel consumption in the agricultural sector are not well recorded, information on electricity consumption is well documented. The increasing consumption of electricity has resulted from the decision taken by several State Governments to have a flat tariff based on horsepower rating of agricultural pump-sets. Little information is available on the end-use for which electricity is being demanded.

Two agricultural operations, known to be energy intensive, namely land preparation and irrigation, were taken up for projecting agricultural energy demands. This involved the projection of area, production and yields for the principal foodgrain and non-foodgrain crops by region and estimating the energy requirements for irrigation and land preparation.

Four major energy intensive foodgrain crops, namely rice, maize, wheat and gram, were considered. These account for 80% of the production of foodgrains and over 60% of the area under foodgrains. A semi-log time trend was projected on the 5-year moving average of total foodgrain production. A moving average was taken to remove the impact of variations due to climatic factors and other unforeseen random occurrences. The production level in 2010 implied an average annual growth rate of 3% over the period 1988-89. A simple time trend was fitted on the 5-year moving averages of yields for each crop (regionwise) to project yields till the year 2010. The gross cropped area is estimated by dividing the production estimates by projected yields.

The non-foodgrain crops covered include groundnut, rapeseed, and mustard (together accounting for 80% of the production and 55% of the area under oilseeds), cotton and sugarcane.

2.2.1.1 Irrigation: Since energy demand for irrigation is dependent largely on the quantity of water required and the height over which it has to be lifted, it was decided to estimate the water requirement for each type of crop that is to be met from underground sources alone. The product of these norms and the gross cropped area gave the quantity of water required for the major crops from underground sources.

Groundwater requirement was estimated using the following equation.

$$U_{it} = \sum_{c} GCA_{ict} * W_c * PI_{ic} * PU_i * E_t \quad .....(Eq.2.1)$$

where,

| | | |
|---|---|---|
| $U_{it}$ | = | the groundwater requirement in region i at time t (cubic meters) |
| $GCA_{ict}$ | = | gross cropped area under crop c in region i at time t (hectares) |
| $W_c$ | = | water requirement for crop c (cubic meters/ha) |
| $PI_{ic}$ | = | Percent of irrigated area in region i for crop c |
| $PU_i$ | = | Percent share of underground sources in region i |
| $E_t$ | = | Index for change in area irrigated |
| i | = | North, South, West, East and North-East regions |
| c | = | rice, maize, wheat, gram, groundnut, rapeseed and mustard, cotton and sugarcane. |

Past trends in yields have been projected upto the year 2009-10 where it has been implicitly assumed that yields would increase due to an increasing percentage of area under HYV, irrigation and fertilizer application. Estimates of irrigation requirements were based on the increasing trend in percentage area under irrigation (gross irrigated area to gross cultivated area) at the all India level. An index, $E_t$, (with 1986-87 as the base year) relating increase in gross irrigated to gross cropped area has been estimated to calculate the increase in regionwise irrigation. The cropwise and regionwise underground water requirements were scaled up using this index. This was done primarily to account for future increases in irrigation which would be essential to bring about increases in yield and cropping intensity.

Once the total water required from underground sources was worked out, it was assumed that the entire demand would be met by using electric pump-sets. Diesel pump-sets are, by and large, used as stand-by pump-sets which are brought into operation if electricity is not available in the quality and quantity desired (TERI, 1990a).

The depth of the water table varies from less than 10 meters to more than 40 meters. In this study, it has been assumed that the average head over which water needs to be pumped is 20 metres. The standard formula for estimating energy requirements E (in kcal) used here is given below.

$$E = \frac{Q * h * t * 860}{102 * n_p * n_m * n_t} \qquad \text{......(Eq.2.2)}$$

where

Q - the rate of discharge (in litres/second)
h - the head over which the water has to be lifted (in metres)
t - the time (in hours)
$n_p$ - the pump efficiency
$n_m$ - the motor efficiency
$n_t$ - the transmission and frictional losses.

An overall system efficiency of 32.4 per cent was assumed based on data compiled on field efficiencies of pump-sets from various studies (Karnataka Energy Consultants).

2.2.1.2 <u>Soil preparation:</u> The trend in stock of tractors per unit of gross cultivated area was observed over the period 1966 to 1987 for each region. These trends were projected upto 2009-10. The product of the gross sown area and the projected

figure of tractors per unit area gave the tractor population.

The annual usage of tractors for land preparation and other agricultural operations was taken at 252.3 hours (TERI, 1991). The horsepower rating of tractors varies from 15 HP to 35 HP with an average rating of 30 HP (Mittal et al., 1985). The fuel consumption norm for tractors was taken as 0.125 l/HP (Mittal et al., 1985) - or 3.75 litres per hour.

The estimates of tractor population, the HP rating, the annual usage and the fuel consumption norm were used to arrive at diesel consumed by tractors for land preparation and other agricultural activities besides transportation.

$$DLP_{it} \quad TP_{it} * R * F * H \qquad \text{......(Eq.2.3)}$$

where $DLP_t$ - diesel used for land preparation at time t
R - Average HP rating of the tractor
F - Fuel consumption per hour (Litres/hours)
H - Hours of usage (annual)

### 2.2.2 Industrial sector

The industrial sector, in particular the manufacturing sector, accounts for a major part of the energy consumption in India. The manufacturing sector contributes about 21 per cent of the gross domestic product in the Indian economy but consumes more than half of the total commercial energy.

Within the manufacturing sector 8 major industries account for nearly 70 per cent of the total industrial energy consumption. These industries are: (1) Iron and steel (2) Aluminium (3) Paper (4) Fertilizer (5) Cement (6) Textiles (7) Engineering industries (electrical and non-electrical) (8) Chemicals and petrochemicals.

Projections of energy demand have been restricted to these 8 industries alone, assuming that the share of these industries in total industrial energy consumption is going to remain more or less at its present level. For those industries that have a homogeneous product, output has been measured in physical units whereas in those industries that produce heterogeneous products, the output has been measured in monetary terms, namely value added.

The outputs from these industries have been projected for the terminal years of various Five Year Plan periods up to the year 2009-10 using growth rates given in the chapter on perspective plan contained in the 7th Five Year Plan document. While these growth rates have been specified only up to the year 1999-2000, it has been assumed that these growth rates would hold good for the next decade as well.

Having projected outputs, specific energy consumption norms have been applied to arrive at energy consumption levels in each of the industries by fuel type.

Some industry specific assumptions are given below :

2.2.2.1 Fertilizer: Nitrogenous fertilizers, which are the most energy intensive, accounted for nearly 70 per cent of total fertilizer production in the country in 1989-90. Within this group of fertilizers, urea is the most important, accounting for nearly 90 per cent of nitrogen consumption. Naphtha, fuel oil, natural gas and coal form the main feedstocks in urea production.

The average specific energy consumption for urea production utilising different feedstocks is given in Table 2.2.

**Table 2.2.** Specific energy consumption norms for urea production

| Feedstock energy | Average specific consumption (G.cal/T.Urea) | Fuel+Feedstock (tonnes/tonne of urea) | Electricity (kWh/tonne of urea) |
|---|---|---|---|
| Fuel oil | 12.70 | 1.18 | 295.00 |
| Naphtha | 13.30 | 1.20 | 457.00 |
| Coal | 29.01 | 6.12 | 1686.63 |
| Gas | 8.95 | 0.641 | 231.00 |

**Source :** TERI (1990).

It has been assumed that all new fertilizer capacity would be natural-gas-based. Existing coal-based fertilizer plants are to be phased out by 1999-2000.

2.2.2.2 Cement: Three types of processes are used in India to manufacture cement, namely wet, dry, semi-dry. The change in the composition of capacity (processwise) for 1977 and 1989 is shown in Table 2.3.

**Table 2.3.** Cement production shares by type of process

| | 1977 (%) | 1989 (%) |
|---|---|---|
| Wet | 65 | 22 |
| Dry | 24 | 75 |
| Semi-dry | 11 | 3 |

**Source :** TERI (1990).

It has been assumed that the dry-process cement manufacture will contribute 75 per cent of cement production, the balance being contributed by the wet-process. Table 2.4 gives energy consumption norms. Table 2.5 gives the share of specific fuels in thermal energy.

**Table 2.4.** Specific energy consumption norms

| | Thermal energy Gcal/T of clinker | Electrical energy kWh/tonne of clinker |
|---|---|---|
| Wet | 2.228 | 26 |
| Dry | 1.402 | 54 |

**Source:** TERI (1990).

**Table 2.5.** Share of different types of fuel in thermal energy supply

| | Wet | Dry |
|---|---|---|
| Coal | 96.5 | 94.7 |
| Fuel oil | 0.5 | 0.7 |
| HSD | 3.0 | 4.6 |

**Source:** TERI (1990).

2.2.2.3 <u>Iron and steel:</u> In India, the production of iron and steel has been based on two broad technological routes:

(1) coke-oven-blast furnace (open hearth): basic oxygen furnace referred to as integrated steel plants.

(2) scrap based Electric Arc Furnace (EAF) steel making: also referred to as the secondary sector or mini steel sector.

<u>Integrated steel plants:</u> Steel industry is one of the largest consumers of energy, both thermal and electrical. For our assessment of energy requirements, we have assumed that Gcal of total energy input required to produce one tonne of crude steel. The shares of different energy sources used that have been assumed are given in Table 2.6.

The specific requirements of coking coal and non-coking coal per tonne of crude steel have been worked out as 1.03 tonnes and 0.55 tonnes respectively. Electricity consumption works out to 570 kWh per tonne of crude steel.

**Table 2.6.** Shares of different energy forms in total energy

| | Percent |
|---|---|
| Coking coal | 70.0 |
| Non-coking coal | 23.8 |
| Hydrocarbons | 2.3 |
| Purchased electricity | 4.9 |

Mini steel plant (Electric Arc Furnace): Electricity is the main energy source used by this sector. Its requirement is in the range of 550 to 700 kWh per tonne of crude steel with an assumed average of 625 kWh.

Sponge iron: Sponge iron or direct reduced iron (DRI) can use non-coking coal or natural gas as the major fuel input Sponge iron replaces imported slag in the electric arc furnace of steel plant. At present, India has a coal based DRI capacity of 0.33 MMT. Recently, the Government has allowed the use of natural gas for sponge iron production The following are the norms which have been taken into account.

| | Coal-based | Gas-based |
|---|---|---|
| Coal (tonne) | 1.1 | - |
| Natural gas (cu.mt) | - | 290 |
| Power (kWh) | 145 | 130 |

**Source:** Government of India (1988), Varadarajan Committee, Planning Commission, New Delhi.

### 2.2.3 Transport sector

The transport sector in India is a major energy (especially oil) consuming sector. Of the total public sector investment on transport, more than 75 per cent is allocated to the development of rail and road transportation systems, with less than 25 per cent being invested in other sub-sectors viz. shipping, inland water transport, air transport etc.

Inadequate investments have led to a decline in the share of railways in total passenger traffic from nearly 62.2 per cent in 1950-51 to as low as 19.8 per cent in 1984-85. In the case of freight traffic, the share of railways declined from a high level of 78.5 per cent in 1950-51 to 41.5 per cent in 1984-85. Road transport makes up for a large part of the balance transportation demand.

In the present analysis, the forecasts of demand for passenger movement [in passenger kilometers (pkm)] have been arrived at by relating it to the levels of population and that for freight movement [in tonne kilometers (tkm)] by relating it to the regional domestic product levels.

2.2.3.1 Relative shares of rail and road in total traffic movement: The rail-road mix given by the Steering Committee on Perspective Planning for Transport Department (GOI, 1988b) for the base year 1986-87 and for the year 2000 were used for interpolating the mix for each of the intermittent years i.e. 1989-90 and 1994-95. The shares of rail and road in the years 2004-05 and 2009-10 were assumed to remain the same as in 1999-2000. The modal shares for each of the years chosen for the study are tabulated below.

**Table 2.7.** Shares of rail and road in total passenger and freight traffic (per cent)

| | Passenger | | | Freight | | |
|---|---|---|---|---|---|---|
| Year | Rail | Road | Total | Rail | Road | Total |
| 1986-87 | 22.30 | 77.70 | 100.00 | 51.5 | 48.5 | 100.00 |
| 1988-89 | 20.92 | 79.08 | 100.00 | 49.0 | 51.0 | 100.00 |
| 1989-90 | 20.22 | 79.78 | 100.00 | 47.8 | 52.2 | 100.00 |
| 1994-95 | 16.76 | 83.24 | 100.00 | 41.5 | 58.5 | 100.00 |
| 1999-00 | 13.3 | 86.7 | 100.00 | 35.3 | 64.7 | 100.00 |
| 2004-05 | 13.3 | 86.7 | 100.00 | 35.3 | 64.7 | 100.00 |
| 2009-10 | 13.3 | 86.7 | 100.00 | 35.3 | 64.7 | 100.00 |

**Source:** GOI (1988b).

Within railways, the share of coal-driven engines was assumed to decline exponentially over time and this becomes negligible or gets phased out completely by the year 2004-05. This is in consonance with the government policy in this respect. Subsequently, the residual shares were ascribed to electric and diesel traction on a proportional basis for each of the years under consideration.

The shares of different modes in road transportation in future were taken as an average of the observed shares in the five years from 1980-81 to 1984-85 (ENCON, 1986).

As far as the passenger movement by bus is concerned, a distinction was made between the volume of inter-regional and intra-regional traffic. The Steering committee [GOI, 1988] states the share of the two to be 16.5 and 83.5 per cent

respectively in 1986-87. In the absence of additional information, similar shares were assumed to be applicable in the future years also.

2.2.3.2 Norms of energy consumption in passenger transport: The quantum of energy consumed in passenger traffic by rail and road was estimated by taking into account the volume of traffic handled by the alternative modes and the fuel intensity of each. The intensity of fuel consumption in railways was obtained from the report of the National Transport Policy Committee [GOI, 1980]. These values of fuel intensity are summarized in Table 2.8.

**Table 2.8.** Fuel intensities of rail passenger transport

| | | | | | |
|---|---|---|---|---|---|
| Steam | 1445.6 | Btu/pkms | or | 0.07 | kg/pkm |
| Electric | 54.6 | Btu/pkms | or | 0.0184-0.017* | kWh/pkm |
| Diesel | 151.2 | Btu/pkms | or | 0.00385-0.0035* | kg/pkm |

**Source:** GOI (1980).

The techno-economic parameters assumed for different vehicles used in road passenger transport are given in Table 2.9 below. The fuel consumption norm for different modes in 2009-10 was taken as that for the most efficient vehicle on the road today with a linear interpolation of values for the intermittent years.

**Table 2.9.** Techno-economic parameters assumed for alternative modes of road passenger transport (l/100 km)

| Vehicle | Capacity | Load | Specific fuel |
|---|---|---|---|
| Bus (suburban) | 52 | 86 per cent | 31.06-30.90 |
| Bus (others) | 52 | 86 per cent | 23.83-23.71 |
| Car/taxi | 5 | 2.6 passenger/vehicle | 7.80-6.42 |
| 2-wheeler | 2 | 1.6 passenger/vehicle | 2.49-2.03 |
| 3-wheeler | 3 | 1.76 passenger/vehicle | 4.53-4.15 |

**Source:** (1) GOI (1989), (2) ENCON (1986), (3) TERI (1991).

2.2.3.3 Norms of energy consumption in freight transport: The demand for energy for carrying freight by rail and road was calculated on the basis of the volume of traffic handled by each mode of freight transport and its intensity of fuel consumption. The values of fuel intensity in railways were taken to be the same as given in the Report of the National

Transport Policy Committee (GOI, 1980) and these are given in Table 2.10 below.

**Table 2.10.** Fuel intensities of rail freight transport

| | | | | |
|---|---|---|---|---|
| Steam | 3576.9 | Btu/pkm | 0.2003 | kg/pkm |
| Electric | 84.6 | Btu/pkm | 0.0248 | kWh/pkm |
| Diesel | 255.5 | Btu/pkm | 0.00596 | kg/pkm |

**Source:** GOI (1980).

In case of the road sector, the carrying capacit and specific fuel consumption of different modes for carrying freight are as presented in Table 2.11 below

**Table 2.11.** Techno-economic characteristics of road freight carriers

| Vehicle | Carrying capacity (tonnes) | Load factor (per cent) | Specific fuel consumpti n (1/100 km) |
|---|---|---|---|
| Truck[1] | 8.0 | 66 | 18.0 |
| Three wheelers[2] | 0.7 | 40 | 10.0 |
| Agricultural tractor[3] | 0.7 | 40 | 12.50 |

**Source:** 1 & 2 from GOI (1989), 3 estimated from TERI (1989a).

### 2.2.4 Urban residential sector

The residential sector in India is an important consumer of commercial energy. There are large rural-urban and regional differences in the composition of fuels which are consumed in this sector. The consumption of biofuels such as charcoal, dung, crop residues, firewood etc. is largely confined to rural India while modern fuels such as electricity, LPG, kerosene and soft coke are largely used in the urban areas These differences in the mix of fuels consumed in rural and urban areas are clearly brought out in Table 2.12.

Energy consumption in households is closely related to the income level of the households. At lower levels of income, the use of energy is mainly restricted to meeting the basic needs such as cooking. As incomes rise, the share of other end-uses such as space cooling and heating, water heating and refrigeration etc., rises rapidly. Furthermore, an increase in the level of household incomes is also accompanied by a

switch from non-commercial to more convenient, modern and commercial sources of energy, namely kerosene and LPG.

**Table 2.12.** Rural-urban differences in energy consumption

| Fuel | Monthly consumption per capita | |
|---|---|---|
| | Rural | Urban |
| **Commercial** | | |
| Soft coke (kg) | 0.19 | 2.61 |
| Kerosene (l) | 0.43 | 0.97 |
| LPG (kg) | - | 0.18 |
| Electricity (kWh) | 0.41 | 2.92 |
| **Biomass fuels (kg)** | | |
| Firewood | 13.17 | 9.73 |
| Vegetable waste | 4.92 | 0.67 |
| Dungcake | 11.80 | 3.00 |
| Charcoal | - | 0.30 |

**Source:** Dharmarajan (1988)

A normative approach was adopted to estimate the consumption of different fuels in the urban domestic sector for each of the years under study (TERI, 1988). Since the actual consumption norms are estimated on a per capita basis, the urban population, classified by income-class and region, was used to work out the total consumption of the fuel in different years.

It was observed that the population distribution for 1988-89 derived from the consumer expenditure survey carried out by the National Sample Survey Organisation (43rd Round) closely follows a log-normal distribution. Future distributions were estimated by fitting a log-normal distribution and specifying three basic parameters namely, the poverty line, proportion of population below it and average monthly per capita expenditure in urban areas in each of the years under consideration.

### 2.2.5 Rural residential sector

Biomass remains the major source of cooking energy in the rural areas in almost all the developing countries. India is no exception (NCAER 1985). The end-use planning approach has been used to estimate the energy requirements for cooking and lighting in this sector.

The actual cooking energy requirements would depend on common food items cooked in the household. This, in turn, would largely be determined by the cropping pattern in a subsistence rural economy based on agriculture. In order to roughly estimate the energy requirements for cooking, National Sample Survey data on consumption of foodgrains was used (NSSO, 1986).

Estimates of the useful thermal energy requirements for achieving cooking tasks are then used to compute the total useful energy requirements for the cereals consumed. It must be emphasised that data on energy requirements for cooking different food items are limited. Needless to say the estimates made in Table 2.13 are approximate for this reason.

Table 2 13 Estimates of useful energy requirement for cereal preparation amor expenditure classes

| | | | Energy requirement for cooking | | | |
|---|---|---|---|---|---|---|
| | | | Monthly expenditure class (in Rs) | | | |
| | | | lowest | middle | highest | All classes |
| | in kJ/kg | kcal/kg | (0-10) | (50-60) | ( > 200) | |
| Rice | 3000 | 717 | 16 | 183 | 237 | 170 |
| Wheat | 3400 | 812 | 4 | 101 | 281 | 110 |
| Jowar | 3000 | 717 | 3 | 41 | 27 | 42 |
| Bajra | 3400 | 812 | 0 | 21 | 36 | 20 |
| Maize | 3500 | 836 | 2 | 18 | 18 | 19 |
| Barley | 2700 | 645 | 0 | 5 | 7 | 5 |
| Small millets | 2500 | 597 | 0 | 4 | 2 | 4 |
| Ragi | 3000 | 717 | 2 | 12 | 9 | 12 |
| Total | | | 26 | 385 | 617 | 381 |

Given a requirement of 380 kcal/capita/day for cooking cereals, the energy requirement norm of 520 kcal per person per day assured in several studies seems to be acceptable.

Hardly any attention has been devoted to the question of the fuel mix for meeting energy demand for rural areas. Of the issues involving demand estimates for rural areas and thereafter estimating the demand for different fuels (especially biofuels), the fuel mix issue is probably the most complex. The most recent data on statewise fuel mix are those presented in the NCAER survey of 1978/79 (NCAER

1985). The analysis here uses this information for computing fuelwise consumption in the domestic sector. Other estimates used for this study are as follows (Table 2.14).

**Table 2.14.** Normative energy requirement: 520 kcal

| | Calorific value | efficiency |
|---|---|---|
| Fuelwood | 4700 | 12% |
| Crop residues | 4200 | 10% |
| Dung cake | 3000 | 12% |

### 2.2.6 Thermal energy requirements

As for biofuels, the methodology followed for projecting the demand for kerosene in the domestic sector of rural areas of India has been somewhat ad hoc in the past. The GOI (1965) norms were 29 l/household/y, GOI (1979) placed the requirement at a marginally higher figure of 29.76 l/hh/y. The 32nd round of the National Sample Survey (NSS) estimated the national average consumption in the rural areas at 37.62 l/hh/y while the NCAER (1985) estimated the national average consumption at 30.05 l/hh/y.

## 2.3 Summary results

<u>5% GDP growth scenario</u>: The sectoral energy demands that have been estimated in the previous sections have been aggregated and corrected for the likely consumption by commercial and other sectors to arrive at total energy demands. The kerosene consumption for lighting purposes is assumed to be accounting for 60 per cent of total kerosene consumption in rural areas

Strangely enough, while electricity demand over the last twenty years has grown at an average annual rate of 8% and coal and oil demands at 5.6% and 5.8% respectively, over the next twenty years the growth in demand for all the above three energy forms has settled around 6%. This could be due to a variety of factors such as conservation, more efficient energy use in agriculture, technology/process change in industry etc. However, natural gas consumption increases at nearly 9% annually.

**Table 2.15.** Demand projections for electricity (GWh)

| | North | West | South | East | N East | All-India |
|---|---|---|---|---|---|---|
| 1989-90 | | | | | | |
| Industry | 14808 41 | 32872 89 | 25077 18 | 16887 83 | 957 80 | 90604 11 |
| Transport | 1463 03 | 1054 92 | 1015 41 | 1102 91 | 296 80 | 4933 08 |
| Domestic | 10250 00 | 11060 00 | 7820 00 | 4050 00 | 650 00 | 33840 00 |
| Agriculture | 21974 70 | 7484 09 | 9413 52 | 6404 29 | 25 46 | 45302 06 |
| Others | 5388 00 | 5830 00 | 4814 00 | 3161 00 | 214 00 | 19409 00 |
| TOTAL | 53885 00 | 58302 00 | 48140 00 | 31606 00 | 2145 00 | 194088 00 |
| 1994-95 | | | | | | |
| Industry | 21381 13 | 47806 74 | 36137 33 | 20975 43 | 1829 66 | 128130 |
| Transport | 1803 55 | 1319 87 | 1208 61 | 1336 61 | 409 21 | 6077 85 |
| Domestic | 15872 91 | 13848 54 | 11258 91 | 5454 38 | 939 98 | 47374 73 |
| Agriculture | 43231 00 | 18802 00 | 16400 00 | 13684 00 | 58 00 | 92175 00 |
| Others | 9143 00 | 9086.00 | 7223 00 | 4606 00 | 360 00 | 30418 00 |
| TOTAL | 91431 00 | 90863 00 | 72228 00 | 46056 00 | 3597 00 | 304175 00 |
| 1999-2000 | | | | | | |
| Industry | 29918 30 | 65622 92 | 51302 51 | 26136 29 | 2384 95 | 175365 00 |
| Transport | 2107 11 | 1434 78 | 1309 77 | 1481 09 | 468 01 | 6800 77 |
| Domestic | 20940 62 | 15895 90 | 13954.56 | 6843 42 | 1183 80 | 58818 30 |
| Agriculture | 48272 00 | 21464 00 | 19143 00 | 16262 00 | 70 00 | 105211 00 |
| Others | 11249 00 | 11602 00 | 9523 00 | 5636 00 | 456 00 | 38466 00 |
| TOTAL | 112487 00 | 116019 00 | 95233 00 | 56358 00 | 4563 00 | 384661 00 |
| 2004-05 | | | | | | |
| Industry | 43632.12 | 93370 25 | 72712 30 | 34810 50 | 3222 73 | 247748 00 |
| Transport | 2973 33 | 1998 37 | 1752 36 | 2023 99 | 673.25 | 9421 29 |
| Domestic | 28003 85 | 18105 75 | 17286 94 | 8490 07 | 1558 53 | 73445 14 |
| Agriculture | 54139 00 | 24540 00 | 22365 00 | 19259 00 | 83 00 | 120387 00 |
| Others | 14305 00 | 15335.00 | 12680 00 | 7176 00 | 615 00 | 50111 00 |
| TOTAL | 143054 00 | 153349 00 | 126796 00 | 71760 00 | 6153 00 | 501113 00 |
| 2009-10 | | | | | | |
| Industry | 64885 22 | 134712 | 106791 | 48545 36 | 4435 42 | 359369 00 |
| Transport | 4175 46 | 2772 06 | 2337 71 | 2750 72 | 962 10 | 12998 05 |
| Domestic | 37503 36 | 22742 50 | 21656 57 | 10920 77 | 2122 83 | 94946 03 |
| Agriculture | 60926 00 | 28095 00 | 26157 00 | 22744 00 | 99 00 | 138021 00 |
| Others | 18610 00 | 20925 00 | 17438 00 | 9440 00 | 847 00 | 67259 00 |
| TOTAL | 186100 00 | 209247 00 | 174379 00 | 94401 00 | 8466 00 | 672593 00 |

**Table 2.16.** Demand projections for coal (million tonnes)

| | North | West | South | East | N East | All-India |
|---|---|---|---|---|---|---|
| 1989-90 | | | | | | |
| Industry | 6 38 | 21 02 | 18 43 | 29.27 | 0 23 | 75 34 |
| Power | 28 09 | 40 22 | 19.86 | 25 93 | 0 89 | 115 00 |
| Transport | 1 74 | 0 80 | 0 72 | 1 41 | 0 48 | 5 15 |
| Domestic | 0 57 | 0 64 | 0 03 | 0 27 | 0.04 | 1 56 |
| Others | 0 34 | 1 11 | 0 97 | 1 54 | 0 01 | 3.97 |
| TOTAL | 37 11 | 63 79 | 40 01 | 58 42 | 1 66 | 201 01 |
| 1994-95 | | | | | | |
| Industry | 10 39 | 32 75 | 27 49 | 37 38 | 0 90 | 108 91 |
| Power | 41 18 | 58 97 | 29 12 | 38 02 | 1 31 | 168 61 |
| Transport | 1 83 | 0 62 | 0 50 | 1 17 | 0 39 | 4 51 |
| Domestic | 0 69 | 0 84 | 0 04 | 0 35 | 0 05 | 1 98 |
| Others | 6 01 | 10 35 | 6 35 | 8 55 | 0 30 | 31 56 |
| TOTAL | 60 09 | 103 53 | 63 50 | 85 47 | 2 95 | 315 56 |
| 1999-2000 | | | | | | |
| Industry | 12 19 | 37 02 | 34 99 | 38 11 | 0 86 | 123 18 |
| Power | 55 58 | 74 10 | 40 33 | 50 83 | 1 31 | 222 15 |
| Transport | 1 69 | 0 40 | 0 31 | 0 88 | 0 33 | 3 60 |
| Domestic | 0 86 | 1 01 | 0.05 | 0 44 | 0 07 | 2 43 |
| Others | 7 81 | 12 50 | 8 41 | 10 03 | 0 29 | 39 04 |
| TOTAL | 78 14 | 125 03 | 84 09 | 100 29 | 2 85 | 390 41 |
| 2004-05 | | | | | | |
| Industry | 16.21 | 47 15 | 41 50 | 42.31 | 0 95 | 148 11 |
| Power | 74 50 | 89 89 | 55 68 | 65 31 | 1 31 | 286.70 |
| Transport | 1 90 | 0 34 | 0 24 | 0 82 | 0 36 | 3 67 |
| Domestic | 0 98 | 1 23 | 0 07 | 0 51 | 0 08 | 2 87 |
| Others | 10 40 | 15 40 | 10 83 | 12 11 | 0 30 | 49 04 |
| TOTAL | 104 00 | 154 00 | 108 31 | 121 05 | 3 01 | 490 39 |
| 2009-10 | | | | | | |
| Industry | 21 68 | 59 35 | 53 35 | 49 40 | 1 09 | 184 87 |
| Power | 104 56 | 115 00 | 80 08 | 88 33 | 1 31 | 389 29 |
| Transport | 2 15 | 0 29 | 0 18 | 0 78 | 0 41 | 3 81 |
| Domestic | 1 11 | 1 47 | 0 08 | 0 57 | 0 10 | 3 33 |
| Others | 14 39 | 19 57 | 14 85 | 15 45 | 0 32 | 64 59 |
| TOTAL | 143 89 | 195.68 | 148.55 | 154 53 | 3 23 | 645 89 |

In terms of percentage shares, it is seen that the industrial sector's consumption of electricity has increased

consumption from the present level of approximately 47 per cent to over 53 per cent in 2009-10. Shares of the domestic and agricultural sectors have declined to 14 per cent and 21 per cent from 17.5 per cent and 23 per cent respectively. The All-India peak demand is seen to increase from a level of 42,000 MW in 1989-90 to 115,000 MW in 2009-10. The growth in peak demand is lower than that of electricity due to the increasing share of the industrial sector which has a much smoother load profile vis-a-vis the domestic sector.

No major changes are seen in the case of coal consumption, with industry and power continuing to account for close to 90 per cent of total coal consumption. However, the share of the power sector has increased from about 57 per cent to 60 per cent at the cost of industrial coal consumption. While the transport sector still consumes nearly 4 million tonnes of coal, in percentage terms its share is almost negligible at 0.5%. An interesting thing to note is that the share of Western region in total coal consumption has declined while that of the Northern and Southern regions has increased. The share of the Eastern region wherein most of the coal is found is also seen to be declining probably due to relatively lower level of developments as compared to the other regions.

The transport sector continues to account for a large part of total oil demand (51%) up to the year 2009-10. The other major consumer is the industrial sector whose share has decreased to about 19 per cent of total oil consumption (24% including power). The share of the domestic sector (12.42%) in this scenario is seen to be declining largely due to the assumption that the per capita kerosene consumption in rural areas would remain at present levels. Thus, kerosene consumption in rural areas is increasing only at the rate of growth of the population. The share of agriculture in oil consumption works out to about 5.5%.

Natural gas consumption would increase at a rate of 9% per annum over the period 1989-90 to 2009-10. The power sector would account for close to 62% of this demand, the balance being made up by industry. Significantly, the share of the North-Eastern sector in natural gas consumption has increased to about 16% from a level of well below 10% today The share of the Western and the Southern regions has increased while that of the North has declined.

**Table 2.17.** Demand projections for oil ('000 tonnes)

| | North | South | West | East | N East | All-India |
|---|---|---|---|---|---|---|
| 1989-90 | | | | | | |
| Industry | 1284 00 | 1490 00 | 3660 00 | 822 00 | 87 00 | 13194 00 |
| Power | 637.25 | 450 58 | 912 45 | 588.39 | 20 34 | 2609.00 |
| Transport | 3897.63 | 4242 17 | 4253 02 | 3644.36 | 645 43 | 18457 60 |
| Domestic | 2145 99 | 2830.98 | 3434 87 | 1626 67 | 462 70 | 10499 00 |
| Agriculture | 2791 78 | 794.56 | 1014.50 | 617 93 | 19 23 | 5238 00 |
| Others | 154 99 | 201.25 | 529 29 | 116.27 | 12 74 | 1014.53 |
| Total | 10911 64 | 10009.40 | 13803 95 | 7415.98 | 1247 38 | 51011 66 |
| 1994-95 | | | | | | |
| Industry | 2985 00 | 3185 00 | 7203 00 | 1884 00 | 264 00 | 15522 00 |
| Power | 926 60 | 655 17 | 1326 76 | 855 56 | 29.57 | 3793 66 |
| Transport | 11095 29 | 7920 76 | 8434 75 | 6709 44 | 1074.57 | 37444 81 |
| Domestic | 2777 41 | 3534 64 | 4116 75 | 1984 85 | 532 68 | 12943 84 |
| Agriculture | 3075 69 | 875 37 | 1117 67 | 680 77 | 21 18 | 5770 67 |
| Others | 1211 26 | 1020 97 | 1634 11 | 703 03 | 91.51 | 4660 88 |
| Total | 22071 42 | 17192 08 | 23833 20 | 12818 08 | 2013 41 | 80135 69 |
| 1999-00 | | | | | | |
| Industry | 3602 00 | 4081 00 | 8936 00 | 2398 00 | 309 00 | 19326 00 |
| Power | 1250 51 | 907 43 | 1667.16 | 1143.64 | 29 57 | 4998.30 |
| Transport | 16215 36 | 10833 35 | 11609 06 | 9352 01 | 1516 88 | 52246 66 |
| Domestic | 3414 32 | 4066 92 | 4701 87 | 2370 00 | 613 01 | 15163.61 |
| Agriculture | 3605 58 | 1056 29 | 1330 48 | 824 32 | 27 95 | 6844.62 |
| Others | 1640 16 | 1367 12 | 2168 06 | 945 61 | 124 26 | 6245 20 |
| Total | 29727 50 | 22311 74 | 30412 96 | 17033 39 | 2621 00 | 104824 1 |
| 2004-05 | | | | | | |
| Industry | 4535 00 | 5342 00 | 11534 00 | 3238 00 | 377 00 | 25026.00 |
| Power | 1676 19 | 1252 84 | 2022 60 | 1469 53 | 29 57 | 6450.72 |
| Transport | 21839 53 | 13858 29 | 15018 02 | 12185 21 | 2011 96 | 68273.01 |
| Domestic | 4209 58 | 4755 69 | 5552.23 | 2898 45 | 729.77 | 18145.72 |
| Agriculture | 4219 69 | 1275 18 | 1579.58 | 992 07 | 36.15 | 8102 67 |
| Others | 2175 88 | 1807.95 | 2910.76 | 1272 14 | 165.56 | 8332.27 |
| Total | 38655 54 | 28291 90 | 38617.42 | 22055.85 | 3349 75 | 134330 |
| 2009-10 | | | | | | |
| Industry | 6029 00 | 7344 00 | 15408 00 | 4525.00 | 479 00 | 33785 00 |
| Power | 2352 69 | 1801 79 | 2587.49 | 1987 44 | 29 57 | 8758 98 |
| Transport | 29415 93 | 17778.18 | 19467 57 | 15931 55 | 2678 29 | 89381 52 |
| Domestic | 5196 22 | 5580 09 | 6528 85 | 3499 72 | 867 88 | 21675.25 |
| Agriculture | 4932 45 | 1540 93 | 1871 96 | 1187 98 | 46 07 | 9579.40 |
| Others | 2924 61 | 2436 34 | 3959 10 | 1734 17 | 222 24 | 11276.46 |
| Total | 50851 26 | 36481 06 | 49823 00 | 28865 72 | 4323 19 | 174456 7 |

**Table 2.18.** Demand projections for natural gas (BAU-low scenario)

| | North | South | West | East | N East | All-India |
|---|---|---|---|---|---|---|
| 1989-90 | | | | | | |
| Industry | 1552 45 | 942 06 | 2942 37 | 303 11 | 130 00 | 5870 00 |
| Power | 1282 48 | 352 58 | 1229.89 | 75 02 | 440 03 | 3380 00 |
| Total | 2834 93 | 1294 64 | 4172 26 | 378 13 | 570 04 | 9250 00 |
| 1994-95 | | | | | | |
| Industry | 1708 08 | 1036 50 | 3237 33 | 333 50 | 143 04 | 6458 45 |
| Power | 6400 58 | 1759 66 | 6138 11 | 374 40 | 2196 12 | 16868 86 |
| Total | 8108 66 | 2796 16 | 9375 44 | 707 90 | 2339 16 | 23327 31 |
| 1999-00 | | | | | | |
| Industry | 2685 02 | 2002 64 | 5308 95 | 531 70 | 250 97 | 10779 29 |
| Power | 8830 20 | 2701 56 | 9773.68 | 374 40 | 4288 79 | 25968 63 |
| Total | 11515 22 | 4704 20 | 15082 63 | 906 10 | 4539 76 | 36747 92 |
| 2004-05 | | | | | | |
| Industry | 3917 32 | 2995 68 | 7873 59 | 764 99 | 377 22 | 15928 80 |
| Power | 9421 35 | 3273 00 | 11547 13 | 374 40 | 6259 29 | 30875 17 |
| Total | 13338 67 | 6268 68 | 19420 72 | 1139 39 | 6636 51 | 46803 97 |
| 2009-10 | | | | | | |
| Industry | 5691 51 | 4624 02 | 11959 38 | 1070 57 | 578 21 | 23923 70 |
| Power | 10360 84 | 4181 17 | 14365 58 | 374 40 | 9390 90 | 38672 88 |
| Total | 16052 35 | 8805 19 | 26324 96 | 1444 97 | 9969 11 | 62596 58 |

The above analysis shows the changing mix of energy sources with the South increasing its share of both coal and gas consumption and thereby electricity consumption as well and the West reducing its dependence on coal while making increasing use of gas. The Eastern region exhibits declining shares in the consumption of almost all energy sources.

Demand projections for biomass fuels are given in Table 2.19.

6% GDP growth scenario : The optimistic growth scenario considers a 6% growth in GDP accompanied by a lower rate of growth of population than that assumed in the earlier scenario. Although part of the energy demand increases as a result of higher growth of GDP is offset by lower population growth, in the aggregate there is a significant increase in energy consumption levels.

**Table 2.19.** Projection of regional consumption of fuels in domestic sector of rural areas (BAU scenario)

| | 1990-1991 | 1994-1995 | 1999-2000 | 2004-2005 | 2009-2010 |
|---|---|---|---|---|---|
| **Firewood (mt/y)** | | | | | |
| North | 21.37 | 23.14 | 25.04 | 27.06 | 29.21 |
| West | 36.29 | 38.87 | 45.57 | 44.36 | 47.24 |
| South | 34.72 | 36.35 | 37.99 | 39.63 | 41.26 |
| East | 19.27 | 20.83 | 22.50 | 24.30 | 26.23 |
| North-east | 6.66 | 7.26 | 7.92 | 8.62 | 9.37 |
| **TOTAL** | **118.30** | **126.45** | **135.01** | **143.97** | **153.31** |
| **Agricultural waste (Air dry) (mt/y)** | | | | | |
| North | 13.69 | 14.79 | 15.95 | 17.20 | 18.5 |
| West | 5.82 | 6.26 | 6.72 | 7 20 | 7.6 |
| South | 11.88 | 12.41 | 12.94 | 13.48 | 14.0 |
| East | 20.74 | 22.65 | 24.73 | 26.99 | 29.4 |
| North-east | 3.19 | 3.48 | 3.79 | 4.13 | 4.4 |
| **TOTAL** | **55.33** | **59.59** | **64.14** | **68.99** | **74.1** |
| **Animal waste (Air dry) (mt/y)** | | | | | |
| North | 28.27 | 30.60 | 33.09 | 35.74 | 38.5 |
| West | 21.23 | 22.81 | 24.47 | 22.20 | 27.9 |
| South | 4.44 | 4.65 | 4.87 | 5.08 | 5.2 |
| East | 24.72 | 26.79 | 29.03 | 31.43 | 34.0 |
| North-east | Neg. | Neg. | Neg. | Neg. | Neg |
| **TOTAL** | **78.67** | **84.86** | **91.45** | **98.44** | **105.8** |
| **Kerosene (mt/y)** | | | | | |
| North | 0.732 | 0.791 | 0.854 | 0.922 | 0.99 |
| West | 0.796 | 0.854 | 0.914 | 0.976 | 1.04 |
| South | 0.684 | 0.716 | 0.747 | 0.779 | 0.81 |
| East | 0.742 | 0.805 | 0.874 | 0.947 | 1.02 |
| North-east | 0.133 | 0.145 | 0.158 | 0 172 | 0.18 |
| **TOTAL** | **3.09** | **3.31** | **3.55** | **3.80** | **4.06** |

**Table 2.20.** Energy demand growth under an optimistic scenario (6% growth in GDP & a low population growth)

| | North | West | South | East | N East | All India |
|---|---|---|---|---|---|---|
| **1994-95** | | | | | | |
| Electricity | 106966 00 | 98421.00 | 78055 00 | 50216 00 | 3244 00 | 336903.00 |
| Coal | 60.60 | 105 90 | 65 50 | 85 60 | 2 00 | 320 80 |
| Oil | 22885 66 | 24829 87 | 17723 35 | 13104 78 | 2064 38 | 83035 54 |
| Natural gas | 8545 50 | 9772.90 | 2893 20 | 746 30 | 2583 70 | 24542 60 |
| **1999-00** | | | | | | |
| Electricity | 133865 00 | 126205 00 | 102693.00 | 61552 00 | 4322 00 | 428637 00 |
| Coal | 82 90 | 134 30 | 92 30 | 102 80 | 2 00 | 414 30 |
| Oil | 31558 05 | 32401 54 | 23481 14 | 17684 72 | 2748 11 | 111131 10 |
| Natural gas | 12569 80 | 15828 30 | 4779 40 | 1059 20 | 5019 80 | 39256 40 |
| **2004-05** | | | | | | |
| Electricity | 169435 00 | 168537 00 | 135224 00 | 77894 00 | 6078 00 | 557168 00 |
| Coal | 117 30 | 173 30 | 126 50 | 129 20 | 2 30 | 548 60 |
| Oil | 41730 30 | 41649 55 | 38891 72 | 22956 01 | 3549 69 | 153086 00 |
| Natural gas | 15112 90 | 20767 70 | 6488 10 | 1481 80 | 7526 80 | 51377 20 |
| **2009-10** | | | | | | |
| Electricity | 211163 00 | 226621 00 | 180548 00 | 99877 00 | 9357 00 | 727566 00 |
| Coal | 171 60 | 234 20 | 186 10 | 173 20 | 2 80 | 768 90 |
| Oil | 55256.89 | 53804 99 | 38597 35 | 29749 76 | 4575 43 | 187637 90 |
| Natural gas | 18949 50 | 28367 80 | 9110 40 | 2092 70 | 11699 50 | 70219 80 |

As is to be expected, growth in demand for individual energy products over the base year 1989-90 is higher than in the earlier scenario with a 6.5%, 6.9%, 6.4% and 9.5% increase in demand for electricity, coal, oil and natural gas respectively. In comparing the energy consumption levels in 2009-10 over the two scenarios, it is seen that while electricity consumption in the latter scenario is higher by 8%, coal consumption is higher by 19%, oil by 7.5% and natural gas by 12%. These variations are due to a different structural mix that has been assumed for the 6% GDP growth scenario.

CHAPTER 3

## Energy supply projections

### 3.1 Introduction

The supplies of major conventional, commercial energy sources like coal, hydrocarbons and electricity in the past decade or more have been normally constrained by availability of resources*. This fact and detailed energy supply expansion programmes consistent with the BAU development strategy have been taken into account while projecting energy supply and likely penetration of renewable energy forms to the year 2010 under the low and high growth scenarios. In other words, relationships between GDP and planned/actual investment in the energy supply subsectors have been extrapolated using GDP growth rates of 5% and 6%. This approach however, could not be used for renewable energy technologies, which have accounted for only 0.1% to 1.2% of annual investment levels in the energy sector during the 1980s and for which, the investment levels are anticipated to increase relatively rapidly in the coming decades.

However, this approach enables us to modify to reasonable levels, the rather ambitious targets for energy supply expansion, as given in various reports# prepared for providing inputs into the Eighth Five Year Plan framework. The methodology adopted for a fuelwise regional supply projection and the results are detailed below.

### 3.2 Coal

The share of coal produced from open-cast mining (using both the shovel-dumper and drag-line techniques) has increased steadily since the mid-1970s, and reached a level of about 64% in 1989/90. This trend is anticipated to continue, and the share of coal from open-cast mines is expected to rise to 67% by 1994/95, 70% by 1999/2000 and 73% by 2004/05. This

---

* Financial resources in the public sector, which influence investment levels in various economic sectors in each five-year planning period.

# Referred to as "Working Group" reports for coal, power etc.

share is assumed to stabilize at 73% after 2004/05, largely because of the poor quality of coal produced by adopting this technology -- free dirt, boulders and other lumpy extraneous matter also get mined along with coal.

Available data from 1980/81 through 1988/89 show that on the average, investment in the coal mining industry accounted for 0.47% of GDP. Maintaining this level of investment in the future, the total investment in the coal industry is projected to increase from about $1.1 billion (1990/91 prices) in 1990/91 to $2.75 billion (1990/91 prices) in 2009/10, i.e. at the rate of about 5% per annum. Table 3.1 gives the projected levels of investment in the coal industry to the year 2009/10.

Available data also show that the investment required to create 1 million tonne per annum (mtpa) mining capacity is different for open-cast and underground mines. Open-cast mines, which are mechanized, entail an average investment cost of $74.7 million/mtpa capacity. Mechanized underground mines require about $100.3 million/mtpa capacity. However, not all new underground mines commissioned in recent years have been fully mechanized -- the non-mechanized ones are less capital intensive. As a result the average capital expenditure incurred on underground mines in the past three years has been $66.9 million/mtpa. It is assumed that the average level of mechanization of underground mines will increase gradually (as the productivity, measured in tonnes of coal output per man-shift, is higher than in non-mechanized mines) to reach full mechanization by the year 2004/05. Moreover, owing to the rapid increases in costs of mining equipment, the real term investment requirements per mtpa of mining capacity are further expected to escalate by 2% per annum.

**Table 3.1.** Coal -- Investment projections

($ million, 1990/91 prices)

| Year | Investment projection | Year | Investment projection |
|---|---|---|---|
| 1989/90 | 1036.6 | 2000/01 | 1772.9 |
| 1990/91 | 1088.4 | 2001/02 | 1861.6 |
| 1991/92 | 1142.8 | 2002/03 | 1954.7 |
| 1992/93 | 1200.0 | 2003/04 | 2052.4 |
| 1993/94 | 1260.0 | 2004/05 | 2155.0 |
| 1994/95 | 1323.0 | 2005/06 | 2262.8 |
| 1995/96 | 1389.1 | 2006/07 | 2375.9 |
| 1996/97 | 1458.6 | 2007/08 | 2494.7 |
| 1997/98 | 1531.5 | 2008/09 | 2619.4 |
| 1998/99 | 1608.1 | 2009/10 | 2750.4 |
| 1999/00 | 1688.5 | | |

On this basis fairly rapid increases in coal production have been projected -- from about 209 million tonnes (MT) in 1988/89 to 573 MT in 2009/10 -- an average growth rate at the rate of 5.2% per annum. The all-India production of coal has been further divided over the regions on the basis of the percentage share of total coal reserves in each region. These are further split between coking and non-coking coal production on the basis of the share of coking and non-coking coal reserves in each region. The results are presented in Table 3.2.

**Table 3.2.** Coal -- Regional break-up of production of coking and non-coking coals (MT)

| UC/OG | CC/NCC | 1989/90 | 1994/95 | 1999/00 | 2004/05 | 2009/10 |
|---|---|---|---|---|---|---|
| WR | Total | 75 16 | 86 71 | 99.17 | 113 99 | 125 87 |
| OC | CC | 0.90 | 1 18 | 1.47 | 1 78 | 2 01 |
| OC | NCC | 54 09 | 70 92 | 88 44 | 106 85 | 120 61 |
| UG | CC | 2 50 | 1 81 | 1 15 | 0 66 | 0 40 |
| UG | NCC | 17 67 | 12 80 | 8 11 | 4 69 | 2 85 |
| SR | Total | 17 80 | 36.76 | 42 37 | 47 33 | 47 84 |
| OC | CC | - | - | - | - | - |
| OC | NCC | 7 54 | 23 36 | 29 44 | 35 95 | 37 51 |
| UG | CC | - | - | - | - | - |
| UG | NCC | 10 26 | 13 41 | 12 93 | 11 38 | 10 33 |
| ER | Total | 102 45 | 157 96 | 223 84 | 301 18 | 395 88 |
| OC | CC | 16 64 | 25 63 | 37 55 | 53 29 | 70 65 |
| OC | NCC | 43 40 | 66 84 | 97 90 | 138 95 | 184 22 |
| UG | CC | 20 66 | 31 90 | 43 06 | 53 07 | 68 69 |
| UG | NCC | 21 75 | 33 59 | 45 34 | 55 88 | 72 32 |
| NER | Total | 1 20 | 3 04 | 4 34 | 3 93 | 3 70 |
| OC | CC | - | - | - | - | - |
| OC | NCC | 0 84 | 2 67 | 4 01 | 3 68 | 3 50 |
| UG | CC | - | - | - | - | - |
| UG | NCC | 0.36 | 0 38 | 0 33 | 0 25 | 0 20 |
| All India | | | | | | |
| OC | CC | 17 55 | 26 82 | 39 02 | 55 07 | 72.66 |
| OC | NCC | 115 95 | 163 79 | 219 78 | 285 43 | 345 84 |
| UG | CC | 23 16 | 33 71 | 44 20 | 53 73 | 69 09 |
| UG | NCC | 51 93 | 60 18 | 66 71 | 72 20 | 85 70 |
| Total | | 208 59 | 284 48 | 369 71 | 466 44 | 573 29 |

Note. NR-Northern Region, NER-North-eastern Region, ER-Eastern Region, WR-Western Region, SR-Southern Region; OC-Opencast; UG-Underground, CC-Coking Coal, NCC-Non Coking Coal,

All non-coking coals produced from open-cast mines are of inferior grade (referred to as INCC or inferior non-coking coals), and those produced from underground mines are of superior grade (referred to as SNCC or superior non-coking coals). INCC include "E", "F" and "G" grade coals*; while SNCC will generally be of "A", "B", "C" and "D" grades**.

Table 3.2 shows that total coal production (CC or coking coals plus INCC plus SNCC) is concentrated in the Eastern Region. While in 1989/90, the Eastern Region accounted for 49.1% of total coal production in the country, this share will increase gradually to 69.1% by 2009/10. The rate of increase of coal production in the Eastern Region is 7% per annum from 1989/90 to 2009/10, compared to 5.2% for the entire country. Although total coking coal production is projected to increase to over 140 MT by 2009/10, a major portion of this will comprise poor quality medium and semi/ weakly coking coals -- which would be more suitable for use as industrial/utility boiler fuel.

It is assumed that lignite production, as a percentage of total coal production, will remain the same as in recent years (after 1985/86), i.e. at 5.7%. Further, as bulk of the lignite reserves are in the Southern Region (Tamil Nadu), a large share of lignite production will remain there. Table 3.3 summarizes the region-wise projections of lignite production. In the Southern Region, the lignite production is projected to increase to 34.51 MT in 2009/10; and in the Western and Northern Regions to 2.18 MT each.

According to experts from GOIs Department of Coal, it may not be possible, for geological reasons, to sustain an annual coal production level of beyond 550 to 600 million tonnes. Therefore, even in the 6% per annum GDP growth case, the coal production levels may not change significantly from the 5% GDP growth scenario.

---

* "E" grade: ash plus moisture content (AMC) of 32 to 35%; useful heat value (UHV) of 3360-4200 kCal/kg; median gross calorific value (MGCV) of 4700 kCal/kg;
"F" grade. AMC above 35%; UHV = 2400 - 3600 kCal/kg; MGCV = 4000 kCal/kg;
"G" grade: AMC above 35%; UHV = 1300 - 2400 kCal/kg; MGCV = 3300 kCal/kg.

** "A" grade: AMC less than 17%; UHV above 6200 kCal/kg; MGCV = 6300 kCal/kg;
"B" grade: AMC of 17-19%; UHV = 5600 - 6200 kCal/kg; MGCV = 6100 kCal/kg;
"C" grade: AMC of 19-24% UHV = 4940 - 5600 kCal/kg; MGCV = 5700 kCal/kg;
"D" grade: AMC of 24-32%; UHV = 4200 - 4940 kCal/kg; MGCV = 5200 kCal/kg.

**Table 3.3.** Lignite -- Regional break-up of production (MT)

| Region | 1989/90 | 1994/95 | 1999/00 | 2004/05 | 2009/10 |
|---|---|---|---|---|---|
| NR | 0 | 0 | 0.56 | 1.27 | 2.18 |
| WR | 1.33 | 1.86 | 1.96 | 2.07 | 2.18 |
| SR | 10.53 | 14.75 | 19.96 | 26.43 | 34.51 |
| Total | 11.86 | 16.61 | 22.48 | 29.77 | 38.86 |

## 3.3 Hydrocarbons

Although the development of the indigenous oil industry has received a high priority since the mid-1970s, only about 25% of the prognosticated hydrocarbon resources have been proven so far. As the exploratory effort is in the initial stages in several basins, geological information required for making reasonable projections on the success of exploratory activity may not be available even with the oil industry. Therefore, the approach adopted is to use normative data for different basins on average gas-oil ratios (GOR), expected discovery index (EDI), indicative costs per metre for exploratory and development drilling and so forth (Table 3.4).

**Table 3.4.** Hydrocarbons - Petroliferous basin particulars

| | Prognosticated Resources (mtoe) | R/P Ratio | Total Dev Drilling Cost ($/metre) (1990-91 prices) | Expected discovery index (Tonnes/metre) | Direct Exploratory Drilling Cost ($/metre) | Gas-Oil Ratio (cu m / tonne) |
|---|---|---|---|---|---|---|
| Onshore | 7772 | | | | | |
| Cambay | 1650 | 10 | 606 5 | 188 | 310 3 | 249 9 |
| Upper Assam | 2280 | 13 | 703 6 | 750 | 646 7 | 476 3 |
| K Godavari | 217 | 15 | 927 9 | 286 | 1443 2 | 2796 5 |
| Cauvery | 166 | 15 | 606 5 | 273 | 1443 2 | 835.1 |
| Bengal | 326 | 15 | 1037 2 | 215 | 1186 7 | 835 1 |
| Assam-Arakan | 2110 | 15 | 1037 2 | 335 | 999 2 | 820 6 |
| K Saurashtra | 263 | 15 | 606 5 | 257 | 310 3 | 835 1 |
| HF & G Valley | 370 | 15 | 1037 2 | 260 | 999 2 | 835 1 |
| Rajasthan | 340 | 15 | 606 5 | 220 | 1140 5 | 4784 7 |
| Mahanadi | 50 | 15 | 1037 2 | 215 | 507.1 | 835 1 |
| Offshore | 12773 | | | | | |
| K Godavari | 543 | 15 | 2573 6 | 1374 | 2760 9 | 549 8 |
| Cauvery | 374 | 15 | 2399 1 | 643 | 2760 9 | 829 1 |
| Bengal | 634 | 15 | 2573 6 | 843 | 2760 9 | 1813 5 |
| K Saurashtra | 497 | 15 | 2573 6 | 832 | 2760 9 | 436 9 |
| Kerala-Konkan | 1630 | 15 | 2181 1 | 696 | 2760 9 | 2919 2 |
| Mahanadi | 1240 | 15 | 2573 6 | 843 | 2760 9 | 1820.3 |
| Andaman | 465 | 15 | 2573 6 | 910 | 2760 9 | 1820 3 |
| Bombay High | 7390 | 15 | 2181 0 | 1701 | 2221 4 | 455 8 |

Source. GOI (1988) and Ministry of Petroleum and Natural Gas

Indicative values of direct exploratory drilling costs per metre for each basin are obtained from GOI (1988). Direct drilling costs account for 58% of total exploratory drilling costs in onshore areas, and 32% in offshore areas [GOI (1989)]. Assuming that exploratory drilling in 2009/10 is in line with present estimates of resource prognostications, it is estimated that the overall average cost of exploratory metre drilled in the year 2009/10 will be $5081.8 (1990/91 prices). Total investments in exploration are first projected to 2009/10, along with drilling costs per metre in onshore and offshore areas. Available data on total investment in hydrocarbon subsector in the 1980s, and projected investment levels as per GOI (1989) indicate that about 0.57% of GDP is earmarked for exploration activity -- which is used as a basis for projecting investments for exploration work (Table 3.5). As total investment in exploration in 2009/10 is projected at $3396.4 million, the total exploratory metreage drilled will be 668,350 metres. Given the exploratory drilling in various basins in 1988/89, the metreage is interpolated basin-wise*.

The basin-wise EDI is then used to compute the annual reserve additions; the prognosticated resources of free gas are treated separately from oil/associated gas reserves. About 25% of the oil and associated gas reserves and 65% of the free gas reserves are assumed to be recoverable. To compute the yearly hydrocarbon production levels basin-wise, an iterative procedure is adopted, keeping in view that. (i) the reserves to production (R/P) ratio of oil and associated gas in each basin at the end of 2009/10 should remain at the levels given in Table 3.4; and (ii) commercial production from a basin begins five years after the first exploratory well is drilled. Further, as the potential to produce free gas is high (about 85% of all possible gas production wil be free gas), it is assumed that its production will be curtailed so that total gas production equals gas demand, and flaring becomes negligible.

---

*It is assumed that the exploratory drilling begins in 1990/91 in the Kutch-Saurashtra (onshore and offshore) basins, and in 1995/96 in the Kerala-Konkan (offshore), Andaman (offshore) and Mahanadi (onshore and offshore) basins.

**Table 3.5.** Hydrocarbons - Projections of investment levels ($ million, 1990/91 prices)

| | Exploration | Production/Development |
|---|---|---|
| 1990/91 | 1344.1 | 727.3 |
| 1994/95 | 1633.7 | 884.0 |
| 1999/00 | 2085.1 | 1128.3 |
| 2004/05 | 2661.2 | 1440.0 |
| 2009/10 | 3396.4 | 1837.8 |

Total oil and associated gas outputs and free gas production potentials are aggregarted region-wise. Table 3.6 presents projected levels of oil and associated plus free gas production potentials. Oil production increases from 30.63 mtoe in 1990/91 to 70.49 mtoe in 2009/10, at the rate of 4.48% p.a.; gas production potential increases faster from 18.10 billion cubic metres (bcm) to 68.27 bcm, at the annual average growth rate of 7.24%.

**Table 3.6.** Hydrocarbons -- Projections of Oil and Gas productio

| | | 1990-91 | 1994-95 | 1999-00 | 2004-05 | 2009-1 |
|---|---|---|---|---|---|---|
| **A. Oil production (MT)** | | | | | | |
| **Onshore** | NR | 0.00 | 0.00 | 0.00 | 0.04 | 0.39 |
| | NER | 5.35 | 6.11 | 7.34 | 9.11 | 11.90 |
| | ER | 0.00 | 0.00 | 0.00 | 0.03 | 0.26 |
| | WR | 4.77 | 5.03 | 5.38 | 5.75 | 6.19 |
| | SR | 0.12 | 0.17 | 0.26 | 0.42 | 0.79 |
| **Offshore** | ER | 0.00 | 0.00 | 0.00 | 0.04 | 1.00 |
| | WR | 20.24 | 23.97 | 29.62 | 36.60 | 45.66 |
| | SR | 0.15 | 0.28 | 0.59 | 1.34 | 4.31 |
| **Total** | | **30.63** | **35.55** | **43.19** | **53.32** | **70.49** |
| **B. Gas production potential (bcm)** | | | | | | |
| **Onshore** | NR | 0.00 | 0.00 | 0.02 | 0.22 | 2.27 |
| | NER | 3.60 | 4.65 | 7.24 | 9.98 | 12.25 |
| | ER | 0.00 | 0.00 | 0.01 | 0.05 | 0.41 |
| | WR | 1.57 | 1.84 | 2.47 | 2.78 | 2.66 |
| | SR | 0.15 | 0.24 | 0.51 | 1.12 | 3.04 |
| **Offshore** | ER | 0.00 | 0.00 | 0.01 | 0.22 | 4.55 |
| | WR | 12.66 | 16.67 | 25.86 | 33.69 | 36.69 |
| | SR | 0.12 | 0.24 | 0.64 | 1.58 | 6.40 |
| **Total** | | **18.10** | **23.63** | **36.75** | **49.64** | **68.27** |

To estimate investments for oil field development activity, the investment in capital equipment required at oil field sites (oil/gas gathering stations, gas-oil/water oil separators etc.) is limited to developmental drilling costs. This is done basin-wise and the results are given in Table 3.5. It is estimated that development drilling nearly doubles from less than 0.6 million metres in 1990/91 to about 1.1 million metres in 2009/10.

While refining capacity will also increase in absolute terms, its share is assumed to decrease from about 92% of total demand for refined products in 1989/90 to below 75% in 1994/95 and remain at that level to the year 2009/10. As per present expectations, the refining capacity by March 1995 will increase to 61.815 million tonnes per annum (mtpa) which implies that refining capacity will meet about 73% of product demand in the low GDP growth scenario. Capacity utilization is assumed at 90% and losses at 6% of the crude throughput. For every 6 mtpa of refining capacity that is added, 1 mtpa of fluidized catalytic cracker (FCC) and 1 mtpa of hydro-cracker (HC) capacity will also be added.* Investments in refineries are estimated at US$ 1116 million, US$ 1844 million, US$ 2207 million and US$ 3089 million during the four successive five-year intervals from April 1990 to March 2010; capacity is assumed to increase from 49.85 mtpa in March 1990 to 138 38 mtpa in March 2000.

Normative capital investment data on natural gas pipelines, obtained from the Gas Authority of India Ltd (GAIL) are : (i) for new pipelines on land, about $75 0 per standard cubic metre per day (SCMD) of gas throughput capacity; (ii) for expansion of throughput of existing pipelines on land, $54.9/SCMD; and (iii) for construction of pipelines offshore (including requisite gas processing facilities etc.), $71.3/SCMD. Along with the estimates of increased gas production and demand, investment on pipelines are computed and presented in Table 3.7. It may be noted that investment in onland gas pipelines is related to demand for gas; while for offshore pipelines, to production of gas from offshore areas.

If the GDP were to grow at 6% per annum, the investment levels for hydrocarbon exploration and production would increase, leading to a higher output. In particular, the

---

* It is assumed that minor light distillates will account for 2.65% of total production of light distillates, minor middle distillates for 1.2% of all middle distillates, and minor heavy ends for 22.5% of all heavy ends.

**Table 3.7.** Investment in natural gas pipelines ($ million, 1990/91 prices)

| | 1990/91 to 1994/95 | 1995/96 to 1999/00 | 2000/01 to 2004/05 | 2005/06 to 2009/10 |
|---|---|---|---|---|
| Onland | 2164 | 2389 | 1790 | 2811 |
| Offshore | 1294 | 740 | 1002 | 2530 |
| Total | 3458 | 3129 | 2792 | 5341 |

investment for exploration and production/development activities would increase to $4139 million and $ 22422 million respectively by 2009/10. The production of oil would increase to 86.02 MT, and of associated plus free gas to a maximum of 75.89 bcm. Refining capacity increase is assumed to remain the same as in the low GDP growth scenario, as a substantial expansion of India's refining capability is evident even in the low growth case. Investment on natural gas pipelines will be $3.8 billion, $3.6 billion, $3.5 billion and $6.7 billion in four successive five-year intervals from 1990/91 to 2009/10.

## 3.4 Power

The power supply industry in India is one of the fastest growing subsectors. The organized Indian power supply industry has accounted for 16% to 18% of total public sector investments since the mid-1970s, and 2.2% to 2.5% of GDP in the 1980s. Such high dependence on planned budgetary resources may not be sustained during the twenty year time-frame to 2010, but significant private sector investment is expected. It is estimated that about 25150 MW of new capacity will be added between April 1990 and March 1995, about 29750 MW from April 1995 to March 2000, 34480 MW from April 2000 to March 2005, and 51770 MW from April 2005 to March 2010*. Table 3.8 gives the detailed break-up region-

---

* According to GOI (1989), about 38000 MW of capacity will come on-stream by March 1995. However, as some projects will get delayed, it is assumed that all sanctioned/ongoing projects and some Central Electricity Authority (CEA) cleared projects will be commissioned by March 1995, while the remaining CEA cleared projects and all "new" projects (that have only been identified until now) will come on stream after 1994/95. As there are very few projects in this shelf that will be commissioned after March 2000, the total capacity additions beyond March 2000 are made up by adding reasonable hydro and other plant capacity (in line with the ratio of additions of various types of generating plant from April 1990 to March 2000).

wise and by type of capacity. As per these projections, the share of hydro capacity falls from 28.7% in March 1990 to about 25.7% in March 2010. The share of total coal-fired thermal capacity (with oil support) reduces from 65% to less than 60%; while gas-based turbine (GT) and combined cycle plant (CCP) capacity increases from 3.7% to 9.6%.

**Table 3.8.** Power generating capacity additions (MW)

| | | Upto Mar 1990 | Apr 1990/ Mar 1995 | Apr 1995/ Mar 2000 | Apr 2000 Mar 2005 | Apr 2005/ Mar 2010 |
|---|---|---|---|---|---|---|
| NR | Hydro | 5942 | 1768 | 5418 | 5429 | 3421 |
| | Coal TPS | 11140 | 1790 | 4520 | 5940 | 9440 |
| | GT/CCP | 1218 | 2030 | 1233 | 300 | 477 |
| | Nuclear | 675 | 470 | 470 | 1000 | 1589 |
| | Total | 18975 | 6050 | 11641 | 12669 | 14927 |
| WR | Hydro | 2248 | 1303 | 250 | 1223 | 1900 |
| | Coal TPS | 15644 | 2870 | 4750 | 4960 | 7883 |
| | GT/CCP | 717 | 2398 | 1845 | 900 | 1430 |
| | Nuclear | 420 | 470 | 0 | 500 | 795 |
| | Total | 19029 | 7041 | 6845 | 7583 | 12008 |
| SR | Hydro | 8060 | 1145 | 1215 | 598 | 1431 |
| | Coal TPS | 7043 | 2100 | 3520 | 4820 | 7660 |
| | GT/CCP | 30 | 863 | 478 | 290 | 461 |
| | Nuclear | 470 | 0 | 470 | 940 | 1494 |
| | Total | 15602 | 4108 | 5683 | 6648 | 11046 |
| ER | Hydro | 1370 | 1371 | 82 | 1310 | 2604 |
| | Coal TPS | 6654 | 5285 | 4020 | 4548 | 7227 |
| | GT/CCP | 190 | 0 | 0 | 0 | 0 |
| | Nuclear | 0 | 0 | 0 | 0 | 0 |
| | Total | 8214 | 6656 | 4102 | 5858 | 9831 |
| NER | Hydro | 421 | 371 | 422 | 720 | 2367 |
| | Coal TPS | 413 | 0 | 0 | 0 | 0 |
| | GT/CCP | 203 | 912 | 1062 | 1000 | 1589 |
| | Nuclear | 0 | 0 | 0 | 0 | 0 |
| | Total | 1036 | 1283 | 1484 | 1720 | 3956 |
| All India | Hydro | 18042 | 5957 | 7387 | 9279 | 11723 |
| | Coal TPS | 40893 | 12045 | 16810 | 20268 | 32210 |
| | GT/CCP | 2358 | 6203 | 4618 | 2490 | 3957 |
| | Nuclear | 1565 | 940 | 940 | 2440 | 3878 |
| | Total | 62587 | 25145 | 29754 | 34477 | 51768 |

Capacity additions envisaged for until March 2000 are estimated largely on the basis of specific projects that have been identified. In particular, these include : (i) projects that have already been sanctioned or/and are under construction; (ii) those which have not yet been sanctioned but have at least been cleared in principle by the Central Electricity Authority (CEA); and (iii) those projects or schemes that have only been identified until now, but on which a final decision on financial support (from the Plan budget) is still awaited.

Using normative capital investment levels for various types of capacity*, total investment levels for generation capacity additions are $15.7 billion, $20.4 billion, $25.5 billion and $41.1 billion in the four successive five-year intervals from April 1990 to March 2010.

Although the Government of India (1980) had recommended that 50% of all investment in the power subsector should be for transmission and distribution (T&D) projects, about 60% of the investment in the 1980s was on installing new generation capacity. Therefore, it is assumed that 60% of all future planned investments in the power subsector will be for capacity expansion. The remainder 40% will be split equally between transmission and distribution.

Based on projections for installed capacity, gross and net generation levels are estimated (Table 3.9). These are derived as follows : (i) for hydro power capacity, the gross generation is assumed to be 2900 kWh/kW of installed capacity and auxiliary consumption about 1% of gross generation; (ii) for coal-fired thermal capacity (which uses unwashed coal), annual gross generation is 4900 kWh/kW and auxiliary consumption is 10% of gross generation; (iii) for gas-fired GT and CCP capacity, the gross generation is 7000 kWh/kW with auxiliary consumption being about 2.5% of gross generation; and (iv) for nuclear capacity, the gross generation is 4500 kWh/kW with auxiliary losses being 10% of gross generation.

---

* Estimated from data obtained from the Central Electricity Authority and Planning Commission as follows: $589.2/kW for hydro capacity, $535.3/kW for coal- fired TPS capacity, $445.8/kW for GT/CCP capacity, and $409.8/kW for nuclear capacity. These figures are in 1990/91 prices, for the year 1980/81. Data also show that capital costs escalate by 1.5% per annum in real terms, for all types of capacity.

**Table 3.9.** Projections for gross generation, net generation and sales (GWh)

| | 1994/95 | 1999/00 | 2004/05 | 2009/10 |
|---|---|---|---|---|
| A Gross generation | | | | |
| Hydro | 69597 | 91018 | 117927 | 151923 |
| Coal TPS | 259395 | 341764 | 441075 | 598904 |
| GT/CCP | 59925 | 92251 | 109681 | 137381 |
| Nuclear | 11273 | 15503 | 26483 | 43932 |
| Total | 400190 | 540535 | 695165 | 932141 |
| B. Net generation | | | | |
| Hydro | 68901 | 90107 | 116747 | 150404 |
| Coal TPS | 233456 | 307588 | 396968 | 539014 |
| GT/CCP | 58427 | 89945 | 106939 | 133947 |
| Nuclear | 10145 | 13952 | 23834 | 39539 |
| Total | 370929 | 501592 | 644488 | 862904 |
| C Sales | 285615 | 386226 | 496256 | 664436 |

It is further assumed that T&D losses will remain more-or-less unchanged from the present day level of 23% of energy despatched from power stations. Table 3.9 also gives the total energy sales projections. It may be noted that these figures correspond only to billable sales -- the actual electricity consumption by consumers will be higher to the extent non-technical or commercial losses occur*. These "billable" sales are projected to increase from 168,269 GWh in 1989/90 to 664,436 GWh by 2009/10, at the rate of 7.1% per annum.

Fossil-fuel requirements for power generation are also expected to increase (Table 3.10). The underlying assumptions are that: (i) 0.65 kg of coal (INCC) and 15 ml of oil (largely fuel oil) will be required per kWh of gross generation obtained from thermal power station (TPS) units; and (ii) about 0.2815 cu.m. of natural gas will be required (on an average) per kWh of gross generation obtained from GTs and CCPs.**

---

* In India, non-technical losses are estimated at over 10% of energy sent out from power stations. In the BAU strategy, this level of non-technical losses is assumed to persist through to 2009/10.

** Although the thermal efficiency of GTs is about 28-30% and that of CCPs (as envisaged at present -- there are no CCPs in operation as yet) is higher at about 43%, an average figure of 35% efficiency in generation is taken. This obviously indicates that both GT and CCP capacity will be in operation in the coming years.

**Table 3.10.** Fuel requirements for power generation

| | 1994/95 | 1999/00 | 2004/05 | 2009/10 |
|---|---|---|---|---|
| Coal (MT) | 168.6 | 222.1 | 286.7 | 389.3 |
| Fuel Oil (000' tonnes) | 3793.7 | 4998.3 | 6450.7 | 8759.0 |
| Gas (mcm) | 16868.9 | 25968.6 | 30875.2 | 38672.9 |

Although a detailed analysis of T & D system expansion is necessary, from an engineering point of view alone it is possible to estimate the total lengths of transmission and distribution lines and substation capacities required (Table 3.11). The following assumptions are made on the basis of past data:

1) 2.5 km of transmission lines ($\geq$66 kV) per MW of installed capacity,
2) 16.0 km of sub-transmission and distribution lines ($\leq$ 33 kV) per MW of installed capacity;
3) 1.9 MVA of substation capacity for transmission system ($\geq$ 66 kV) per MW of installed capacity;
4) 1.8 MVA of substation capacity for subtransmission and distribution system ($\leq$ 33 kV) per MW of installed capacity.

**Table 3.11.** T & D system expansion

| | 1994/95 | 1999/00 | 2004/05 | 2009/10 |
|---|---|---|---|---|
| >=66 kV (ckt-km) | 62864 | 74386 | 86191 | 129420 |
| <=33 kV (ckt-km) | 409095 | 487320 | 566680 | 847886 |
| >=66 kV s/s (MVA) | 47776 | 56534 | 65505 | 98359 |
| <=33 KV s/s (MVA) | 46023 | 54824 | 63752 | 95387 |

For purposes of making T&D system expansion projections, it is assumed that with the addition of RET capacity, substation and line capacity only at and below the 33 kV voltage level will need to be augmented, and in the same manner (16 ckt-km/MW of lines and 1 8 MVA/MW of substation capacity).

So far, inter-regional transmission links have been largely for mutual exchange of power between two neighbouring grid systems. However, considering the uneven distribution of the energy resources, generation capacity expansion may be so planned as to overcome deficiencies in one region or state by establishing generating capacity in a neighbouring region

and transmitting bulk power. This approach will enable the consolidation of integrated grid operations.

The projections presented in Tables 3.8 through 3.11 correspond to a 5% GDP growth rate. If GDP were to grow by 6%, it is assumed that only GT/CCP capacity could increase by March 1995, while both TPS and GT/CCP capacity additions may occur thereafter. With this in view, capacity additions during four successive five-year intervals between April 1990 and March 2010 were worked out to be 25873 MW, 32102 MW, 39001 MW and 61405 MW respectively. Total investment in the power subsector (including investment in T & D systems) is expected to be $26.7 billion, $36.6 billion, $48.1 billion and $81.1 billion in the four five-year periods respectively. Total fuel requirements are projected to rise to 435.3 MT of coal, 9.8 MT of fuel oils and 44.2 bcm of gas by 2009/10; and total (billable) sales to 728,137 GWh.

## 3.5 Renewable energy technologies

Although there has been a sharp increase in the funding of Renewable Energy Technologies (RETs) in the last ten years, the fund allocation has remained small in comparison to the energy sector's total outlay. Despite the relatively low investment levels in the R&D and utilisation of RETs in the 1980s, the investment trends do appear encouraging. This perhaps prompted the Department of Non-Conventional Energy Sources (DNES), to propose an extremely ambitious perspective plan in 1987 for renewable energy utilization to the year 2000/01, with an expenditure of about $26 billion. The proposed targets for power generation using RETs were some 15000 MW by the turn of the century---the major share coming from biomass, wind, small hydro and solar photovoltaic. This target however, is unrealistic and the constraints that are likely to be faced in implementing these programmes have not been adequately addressed by the DNES.

The extent to which a given RET will actually get installed will depend on several factors like the state of technology, future developments, Government policies, economics of generation, infrastructure, industrial capability, organisational and institutional aspects, availability and channelisation of funds and the turnover capacity in national and international markets.

In the BAU strategy, it is assumed that there will be no special drive or effort to set-up significant wattage or number of RET devices, and the existing constraints will

continue. On the basis of the potential, level of technology and economics, it appears that only biogas, windfarms and the small and microhydel technologies can play a significant role by the year 2010.

Detailed analysis was carried out to examine the constraints, issues related to grid inter-connection, logistics, turnover capacities within and outside the country, and the future developments in the technology etc. to arrive at realistic values for yearly increments in the installations of these devices. Attempts were made to incorporate all possible factors including the lifetime of devices and a certain phasing out of capacity in arriving at the figures for 2010. The projected installations are given in Table 3.12. All new windfarm capacity additions are assumed to be in the Western, Southern and Eastern regions only, which will account for 45%, 45% and 10% of capacity additions respectively. New small hydro capacity will be added in all regions, as follows: 31% in the Northern Region, 15% in the Western Region, 35% in the Southern Region, 10% in the Eastern Region and 9% in the North-east.

It is assumed that the capacity utilisation factors for windfarms and small hydro installations will be 15% and 22% respectively; their availability factors at times of system peak demand will be 0.1 and 0.3 respectively; their investment costs (in 1990/91 prices) will be $1654/kW and $1838/kW respectively, and annual O&M costs at 3.33% and 2% of capital costs respectively.

**Table 3.12.** Projected capacity/installations of RETs by 2010

| | |
|---|---|
| **Wind energy technologies** | |
| windfarms | about 500 MW |
| **Mini/Small/Microhydel** | |
| Canal Drop Schemes | about 850 MW |
| **Biogas Plants** | |
| 2 Cubic Meters | 43,64,000 (numbers) |
| 4 Cubic Meters | 42,44,278 (numbers) |
| **Gasifier based power generation** | |
| 100-500 kW systems | 50 MW |
| **Photovoltaic systems** | |
| Aggregate capacity of systems in all ranges | 60 MW |

### 3.6 Biomass fuels

3.6.1 Fuelwood

The supply of fuelwood is difficult to estimate. Current annual figures range anywhere from 66 to 120 MT. Details are given in Chapter 1, Section 2.5.1. Regionwise estimates are shown in Table 1.14.

3.6.2 Crop residues

The quantum of crop residues in a region depend on the cropping pattern and harvesting methods. Estimation of residues has been restricted to important non-fodder crop residues. These are rice husk, maize cob, groundnut shells, cotton sticks, bagasse (of the order of 67 MT/year in 1988-89 - most of which is already used as a thermal source in the sugar industry), coconut-fibre and shell, pulses straw and jute sticks. Projections are shown in Table 3.13

**Table 3.13.** Regional projections of crop residues

| Region | 1988-89 | 1994-95 | 1999-2000 | 2000-05 | 2005-10 |
|---|---|---|---|---|---|
| Northern | 49 662 | 59 296 | 68 732 | 79 679 | 92 370 |
| Western | 32 476 | 38 777 | 44 947 | 52 106 | 60 405 |
| Southern | 37 393 | 44 647 | 51 752 | 59 994 | 69 550 |
| Eastern | 18 514 | 22 106 | 25 624 | 29 705 | 34 436 |
| North-Eastern | 3 004 | 3 587 | 4 158 | 4 820 | 5 587 |
| Andaman & Others | 0 164 | 0 196 | 0 227 | 0 264 | 0 305 |
| Total | 141 214 | 168 609 | 195 440 | 226 568 | 262 654 |

3.6.3 Dungcakes

As mentioned in Chapter 1, section 2.5.3, the availability of dung is not going to increase very significantly over the current levels. It is estimated that the annual supply will stabilise by 1994-95 and the amount of wet dung fuel (MT) across regions would be -- Western (63228), Southern (25785), Eastern (92943), Northern (120388) and North Eastern (3) giving a total of 302348 for the country.

### 3.7 Energy shortages

It is clear from the demand forecasts presented in Chapter II, and the supply projections in preceding sections of Chapter III that significant energy shortages will characterize the Indian economy.

The shortages estimated under the BAU strategy of development, under 5% and 6% per annum GDP growth assumptions are given for various energy sources below.

### 3.7.1 Coal shortages

As coal output is not likely to change significantly under the two GDP growth scenarios, coal shortages are higher in the 6% GDP growth case. It is assumed that the poor quality coking coals will be used in industry and utilities as boiler fuel, and that there will be adequate production of prime coking coals to meet a large share of the requirements of the steel industry. It is further assumed that nearly all lignite produced will be used for power generation.

With these assumptions, the net non-coking coal shortages will be as shown in Table 3 14 In the low GDP growth case, marginal shortage (of nearly 30 MT) appears by the year 2009/10. In the high GDP growth case of course, the overall non-coking coal shortages rise to about 153 MT by 2009/10.

**Table 3.14.** BAU strategy - Regional coal shortages (MT/year)

| | 1994/95 | 1999/00 | 2004/05 | 2009/10 |
|---|---|---|---|---|
| Non-coking coal (5% GDP growth case) | | | | |
| NR | 59.8 | 77.6 | 102.7 | 141.7 |
| WR | 15.6 | 25.0 | 39.2 | 69.1 |
| SR | 12.6 | 22.7 | 35.4 | 67.2 |
| ER | -71.5 | -124.6 | -183.4 | -247.8 |
| NER | - 0.1 | - 1.5 | - 0.9 | - 0.5 |
| INDIA* | 16.4 | - 0.8 | - 7.0 | 29.7 |
| Non-coking coal (6% GDP growth case) | | | | |
| NR | 60.8 | 82.6 | 115.7 | 169.8 |
| WR | 18.3 | 33.8 | 58.7 | 107.9 |
| SR | 14 8 | 30.4 | 53.8 | 105.0 |
| ER | -71.1 | -121.7 | -175.2 | -229.1 |
| NER | - 0.7 | - 2.0 | - 1 3 | - 0.6 |
| INDIA* | 22.0 | 23.1 | 51.7 | 153.0 |

Note: (i) Negative numbers denote surplus supply.
(ii) The demand for coking coal presented in Chapter 2 is for cleaned coking coal. Washery yields of coking coals are taken as 55% (Source = Dept.of Coal, GOI), middlings as 35% and rejects as 10%. The middlings are of a quality similar to steam-grade non-coking coal, and are assumed to be used for power generation.
* Net imports.

Coal import requirements, particularly in the high GDP growth case are many-folds larger than coal imports at present. Even to physically handle such levels of imports, India would need to undertake a massive effort to develop port facilities, as well as enter into long term import agreements with various coal exporting nations, including Australia and China. Of course, to the extent the quality of imported coal will be better (higher GCV) than that of indigenous coal, the import requirements will be less.

There are of course, inter-regional disparities in the coal availability situation. It is assumed that as at present, coals produced in the Eastern Region will be transported to the Northern, Western and Southern Regions.

3.7.2 Oil and gas shortages

India will remain a net oil importer, and will continue importing crude oil and certain refined products (particularly LPG, HSD, LDO, FO and other minor products), but will be in a position to export MS, naphtha and ATF in the low growth case. In the high growth case however, shortages of ATF also appear. Table 3.15 summarizes the net import requirements of crudes and products As discussed in section 3.3, there will be no gas shortages.

**Table 3.15.** BAU strategy -- Net imports of crude oil and refined products (MT per annum)

| | 1994/95 | 1999/00 | 2004/05 | 2009/10 |
|---|---|---|---|---|
| **5% per annum GDP growth case** | | | | |
| Crude | 20.1 | 30.2 | 41.4 | 54.0 |
| Light distillates | 1.1 | -0.4 | -0.6 | -1.3 |
| Middle distillates | 24.9 | 31.5 | 39.6 | 49.3 |
| Heavy ends | 6.5 | 10.8 | 14.4 | 20.3 |
| All products | 32.6 | 42.0 | 53.4 | 68.4 |
| **6% per annum GDP growth case** | | | | |
| Crude | 18.0 | 25.5 | 32.7 | 38.5 |
| Light distillates | 2 1 | 2.0 | 1.7 | -0.4 |
| Middle distillates | 27.8 | 38 2 | 58.4 | 63.1 |
| Heavy ends | 5 8 | 8.3 | 12.6 | 19.6 |
| All products | 35.7 | 48.6 | 72.7 | 82.2 |

The steep rise in petroleum imports reflects declining self-sufficiency in oil as growth in supplies will not keep pace with demand increases. It is also evident that major efforts will need to be made to curtail the demand for middle-distillates, particularly HSD.

3.7.3 Power shortages

Power supplies from both RET installations and conventional generating capacities are considered while computing power shortages. In both GDP growth rate cases, power shortages reduce considerably from present levels. In fact, power surpluses also appear in some regions. In this situation, the power surplus regions will export power to neighbouring regions.

According to our projections, both Eastern and Northeastern regions have surplus capacity (Table 3.16).

**Table 3.16.** BAU strategy - power shortages (%)

| | 1994/95 | 1999/00 | 2004/05 | 2009/10 |
|---|---|---|---|---|
| **5% per annum GDP growth case** | | | | |
| (a) % Energy shortage | | | | |
| NR | 10.71 | -3.99 | -7.61 | -8.11 |
| WR | 1.02 | -0.32 | 7.19 | 12.33 |
| SR | 20.17 | 19.78 | 22.16 | 22.45 |
| ER | - 3.40 | - 9.10 | - 11.30 | - 16.78 |
| NER | -150.85 | -240.92 | -265.52 | -326.03 |
| INDIA | 6.02 | -0.56 | 0.77 | 0.95 |
| (b) % Peak shortage | | | | |
| NR | 17.49 | -0.27 | -6.87 | -6.53 |
| WR | 10.45 | 9.76 | 14.44 | 17.61 |
| SR | 7.91 | 10.36 | 16.01 | 18.38 |
| ER | 0.96 | -2.08 | - 6.35 | -15.01 |
| NER | -138.71 | -213.85 | -242.67 | -333.21 |
| INDIA* | 9.01 | 2.52 | 2.33 | 1.79 |
| **6% per annum GDP growth case** | | | | |
| (a) % Energy shortage | | | | |
| NR | 22.76 | 9.98 | 4.67 | -2.28 |
| WR | 6.99 | 4.38 | 10.71 | 11.72 |
| SR | 25.41 | 23.57 | 22.66 | 17.42 |
| ER | 5.16 | -2.41 | -9 06 | -21.88 |
| NER | -198.80 | -289.56 | -306.91 | -330.40 |
| INDIA* | 14.01 | 6.79 | 5.54 | 0.12 |
| (b) % Peak shortage | | | | |
| NR | 29.32 | 14.72 | 7.51 | 1.14 |
| WR | 16.54 | 14.69 | 18.85 | 18.41 |
| SR | 15.17 | 16.35 | 18.87 | 15.79 |
| ER | 10.36 | 5.94 | -1.42 | -16.91 |
| NER | -174.44 | -247.31 | -269.30 | -334.02 |
| INDIA* | 17.84 | 11.29 | 9.32 | 3.26 |

In this situation, power wheeling arrangements may be developed to export surplus power from the Northeast to the South and West (and Northern Region too, if it has shortages) via the Eastern Region. In fact, this may very well reflect the situation that hydropower development in the Northeast accelerates considerably beyond present levels.

### 3.7.5 Reconciling demand and supply of biofuels

An important characteristic of a biofuel based energy system is that supply is of a localised nature*. Any accounting, therefore, at the aggregate level is likely to be misleading since scarcity or surplus is at a local level. Consequently, the interventions (which may take the form of supply enhancement, demand management and/or encouraging fuel switching) may be aimed at the wrong target group or area. This caveat should be kept in mind when viewing the supply/demand balance presented at an aggregated level.

The present assessment of the biofuel balances is first carried out at the state level and thereafter aggregated at the regional level. It must however, be reiterated that neither the state nor the region are appropriate levels for designing interventions as far as biofuels are concerned.

3.7.5.1 Fuelwood demand and supply: The demand and supply for fuelwood has been dealt with in the individual sections on demand and supply. The demand was found to be significantly higher than the sustainable yields in all states other than those in the north-east The ratio of the demand to sustainable yields from forests, aggregated to the regional level, are presented in Table 3.17. It must be emphasised, however, that forests are not the only source of fuelwood. There are numerous other sources though there are no reliable data. The National Commission on Agriculture estimated that fuelwood from these sources varies from 50-90% of the total consumption depending on the geographical location of the area in question.

---

* The demand, in general, is also localised except when there are demands from urban and peri-urban areas. These demands and the resulting markets in urban and semi-urban areas for woody biofuels are believed to be among the major causes for deforestation (see for example, CSE 1985).

**Table 3.17.** Ratio of fuelwood consumption to sustainable forest yields

| | 1991 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|
| North | 4.9 | 5.3 | 5.7 | 6.1 | 6.5 |
| West | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 |
| South | 4.6 | 4.8 | 5.0 | 5.2 | 5.4 |
| East | 3.5 | 3.7 | 4.1 | 4.4 | 4.7 |
| North-East | 0.5 | 0.6 | 0.7 | 0.7 | 0.8 |
| **Average** | 2.8 | 3.0 | 3.2 | 3.4 | 3.6 |
| **(Average excluding NE)** | 3.7 | 3.9 | 4.2 | 4.4 | 4.7 |

One clear implication of Table 3.17 is that intervention for fuel substitution in the rural domestic sector deserves a priority in the Northern parts of the country.

3.7.4.2 <u>Agricultural residues</u>: As indicated in section 3.6, only non-fodder residues were considered while estimating their availability. The consumption-to-production ratio of the non-fodder residues (Table 3.18), shows that the availability position of the non-fodder residues appears adequate in all the regions except the east and the north-east. It is likely that in these regions, some fodder residues are also being diverted for use as fuels.

**Table 3.18.:** Consumption to production ratios of agricultural wastes

| | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|
| North | 0.25 | 0.23 | 0.22 | 0.20 |
| West | 0.16 | 0.15 | 0.14 | 0.13 |
| South | 0.28 | 0.25 | 0.22 | 0.20 |
| East | 1.02 | 0.97 | 0.91 | 0.86 |
| North-East | 0.97 | 0.91 | 0.86 | 0.80 |
| **Average** | 0.35 | 0.33 | 0.30 | 0.28 |

The use of the ratio as an indicator of supply options may be misleading for one important reason. Some non-fodder residues may already be in use and therefore may not be actually available. A good example is bagasse, most of which already finds use in the sugar industry. Table 3.19 lists the consumption-to-production ratios for the regions after deducting the bagasse production. The country average of the consumption-to-production ratio in this case goes above 0.6, indicating that most of the non-fodder residues

already have competing uses as a fuel in the domestic sector.

**Table 3.19.** Consumption to production ratio of agricultural residue (without bagasse)

| | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|
| North | 0.73 | 0.68 | 0.63 | 0.61 |
| West | 0.25 | 0.23 | 0.21 | 0.20 |
| South | 0.52 | 0.47 | 0.42 | 0.38 |
| East | 1.24 | 1.16 | 1.10 | 1.04 |
| North-East | 1.26 | 1.19 | 1.12 | 1.05 |
| **Average** | 0.66 | 0.61 | 0.57 | 0.53 |

Animal waste: Like other biofuels, the supply position of animal wastes does not appear comfortable (Table3.20). It is however, possible to increase the availability of this waste resource by about 10-25% by increasing the collection efficiency.

**Table 3.20.** Consumption to availability ratio of dung

| | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|
| North | 1.65 | 1.78 | 1.92 | 2.07 |
| West | 1.80 | 1.93 | 2.07 | 2.21 |
| South | 0.90 | 0.94 | 0.99 | 1.03 |
| East | 1.11 | 1.21 | 1.31 | 1.41 |
| North-East | | | | |
| **Average** | 1.40 | 1.51 | 1.63 | 1.75 |

CHAPTER
4

# Environmental impacts of energy development (BAU)

## Introduction

Environmental impacts resulting from energy production and use vary widely. The combustion of fossil fuels results in emissions of pollutants such as particulate matter, oxides of sulphur and oxides of nitrogen which, in addition to affecting the health of human beings, also adversely affect plant and animal life. The construction of a large dam leads to the creation of a reservoir that often results in large scale displacement of people along with the loss of existing forests and agricultural land. Nuclear plants have radiological concerns, the health effects of which can extend to more than one generation.

The diversity of environmental impacts arises not only because of the different types of energy fuels/technologies, but even within the same type, the potential for damage may vary from location to location. Consider, for example, hydroelectric plants. The magnitude of impacts would depend upon various factors such as the terrain and vegetation of the catchment area, the size of the reservoir, the type of area submerged, etc. Again, consider the case for thermal power plants. Although technology-wise there would be little difference, the magnitude of the impact would largely depend upon the location of the plant. If the plant is located in an area where existing levels of pollutants are already high, it would have a greater potential for damage than if it is located in an area with low ambient pollution levels. An example is a city versus a rural siting where, for the former, not only is the ambient air quality often over critical levels but also a greater number of people are exposed to pollution.

In this exercise, wherever applicable, an attempt has been made to capture some of the locational impacts associated with energy activities. A description of the environmental impacts arising from the BAU strategy for the five regions is given in the sections that follow.

## 4.2 Environmental impacts of energy production

### 4.2.1 Coal mining and thermal power generation

4.2.1.1 Coal mining: The environmental impacts from coal mining include loss of forest cover, loss of production (forest, agriculture and grasslands), loss of topsoil and soil erosion, surface water pollution, lowering of water table, hazards of ore transport (damage to vegetation, soil, drainage, agriculture, water quality), sediment production and discharge, fire hazards and air pollution and displacement of people.

Since coal production is predicted to remain the same under 5 and 6 per cent GDP growth rates, the impacts from coal mining also would remain the same. The total spread of coalfields in India is over 3.47 Mha while the extent of area under coal mining till 1989-90 was of the order of 23,269 ha (GOI, 1989). The average amount of forest land depleted per tonne of coal production has been determined regionwise. Using these figures in conjunction with production estimates up to the year 2010, the total amount of forest land depleted is given in Table 4.1. The maximum forest area lost is in the eastern region the damaged forest type being of the Tropical Dry Deciduous type.

**Table 4.1.** Projections of additional forest area depleted (5 % GDP growth rate)

| Region | Average area (ha/MT) | 94/95 | 99/2000 | 2004/05 | 2009/10 | Total | Forest type |
|---|---|---|---|---|---|---|---|
| | | (ha) | | | | | |
| West | 229.10 | 4822 | 2109 | 2508 | 2011 | 11450 | TDD+TMD |
| South | 742.37 | 9652 | 2544 | 2249 | 1909 | 16355 | TMD |
| East | 141.32 | 8567 | 7021 | 8242 | 10092 | 33922 | TDD |
| North-east | 97.83 | 204 | 87 | 0 | 0 | 291 | TWE |
| All India | | 23245 | 11761 | 13000 | 14012 | 62018 | |

TDD: Tropical dry deciduous
TMD: Tropical moist deciduous
TWE: Tropical wet evergreen

The impact of coal mining in terms of the number of families displaced has been estimated based on the following norms: opencast, 173/MT of coal; underground, 32/MT of coal (GOI 1988). These are presented in Table 4.2.

**Table 4.2.** Number of families displaced
(5 % GDP growth rate)

| Region | 90/91-94/95 | 95/96-99/2000 | 2000/01-04/05 | 05/06-09/10 | Total from 90/91-2009/10 |
|---|---|---|---|---|---|
| West | 3649 | 2277 | 2393 | 1787 | 10106 |
| South | 1640 | 642 | 688 | 539 | 3508 |
| East | 6954 | 6160 | 7906 | 8944 | 29964 |
| North-east | 324 | 160 | 0 | 0 | 494 |
| All India | 12568 | 9239 | 10986 | 11270 | 44063 |

Abandoned coal mining operations in the past have left more than 10 000 ha of land totally damaged due to subsidence of surface land and mine spoil dumps. Though the government has laid down certain standards to be followed by mining companies, these are generally not complied with. Based on normative estimates of 0.0003 ha of land damage per tonne of coal output and assuming that 90% of the lifetime overburden is used for refilling the excavated mines, it is estimated that by the year 2010, another 7 000 ha of land would be affected by mine spoil dumps. Regionwise details are presented in Table 4.3. These estimates do not include the area damaged due to subsidence and therefore are on the lower side.

**Table 4.3.** Projections of area required for external dump
(5 % GDP growth rate)

| Region | 94/95 | 99/2000 (in ha) | 04/05 | 09/10 | Total |
|---|---|---|---|---|---|
| West | 633 | 395 | 415 | 310 | 1753 |
| South | 260 | 111 | 119 | 93 | 583 |
| East | 1067 | 972 | 1285 | 1417 | 4741 |
| North-east | 55 | 28 | 0 | 0 | 83 |
| All India | 2015 | 1506 | 1819 | 1820 | 7160 |

4.2.1.2 Thermal power plants. The bulk of Indian coal is characterized by high ash (30-40%) and low sulphur content (below 0.5% except for northeastern coal), the combustion of which produces large quantities of flyash and bottom-ash. The particulate matter in the flue gas is controlled by Electrostatic Precipitators (ESP), the new units having efficiencies that are over 99%. The solid waste products from combustion (consisting of flyash removed from the ESP and the bottom-ash) pose a major waste disposal problem because of large areas of land that are required and the consequent deterioration of soil quality.

4.2.1.3 Impact on air quality. Before discussing the impacts of power plants on air quality, the general approach adopted for capturing local aspects of air pollution is presented. Air pollution has local, regional and global ramifications, the concerns being impact on human health, ecosystem degradation due to acid rain, and the consequences of global warming, respectively. Local impacts are site specific, the damage potential of the energy activity depending upon the additional pollutant load and the current ambient air quality. These impacts are usually estimated using dispersion models based on technical (emission rates, design features, etc.) and on meteorological features (wind direction, atmospheric stability, etc.). This kind of an exercise, however, is well beyond the scope of this study Instead, a more simplistic approach has been developed wherein a region is mapped into three zones, based on the damage potential. These are (1) areas that are heavily polluted, (2) areas that are moderately polluted, and (3) areas that are relatively clean. Based on the data available for 33 cities in India, it was seen that only TSP levels exceeded the standards, with both $SO_x$ and $NO_x$ on an average being well within the standards (with the exception of two cities). Therefore, these zones have been defined based on TSP levels as follows.

Zone 1: Heavily polluted areas, where ambient annual average TSP levels are above 200 $mg/m^3$ (1991 proposed standards).

Zone 2: Moderately polluted areas, where ambient annual average TSP are between 150 to 200 $mg/m^3$.

Zone 3: Relatively clean areas, where the ambient annual average TSP levels are below 150 $mg/m^3$.

This zoning scheme has also been followed wherever impacts on air quality have been determined.

Emissions from thermal power plants are given for all the zones and regions in Table 4.4 (5% GDP growth rate). Since location specific expansion plans were available for the

period 1990-2000, these have been mapped into the respective zones. For the remaining period, it is assumed that no new plants will be located in Zone 1 (critical zone). The capacities have been distributed in the ratio of 1:2 for Zone 2 and Zone 3 respectively.

**Table 4.4.** Emissions from thermal power plants

(thousand tonnes) (5 % GDP growth rate)

| | $SO_x$ | | | CO | | | $NO_x$ | | | TSP | | | HC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **North** | | | | | | | | | | | | | | | |
| 1990 | 106 | 84 | 36 | 3 | 2 | 1 | 111 | 88 | 38 | 3114 | 2464 | 1073 | 2 | 1 | 1 |
| 1995 | 122 | 100 | 72 | 3 | 2 | 2 | 128 | 105 | 76 | 3584 | 2934 | 2137 | 2 | 1 | 2 |
| 2000 | 198 | 148 | 120 | 5 | 3 | 3 | 208 | 155 | 126 | 5824 | 4345 | 3548 | 3 | 2 | 3 |
| 2005 | 198 | 227 | 278 | 5 | 5 | 7 | 208 | 234 | 284 | 5824 | 6563 | 7983 | 3 | 3 | 5 |
| 2010 | 198 | 347 | 517 | 5 | 8 | 13 | 208 | 360 | 535 | 5824 | 10087 | 15032 | 3 | 5 | 9 |
| **West** | | | | | | | | | | | | | | | |
| 1990 | 119 | 120 | 141 | 3 | 3 | 4 | 125 | 126 | 148 | 3496 | 3531 | 4150 | 2 | 2 | 2 |
| 1995 | 135 | 158 | 196 | 3 | 4 | 6 | 142 | 166 | 206 | 3966 | 4651 | 5774 | 2 | 3 | 3 |
| 2000 | 213 | 234 | 393 | 5 | 6 | 11 | 223 | 246 | 412 | 6251 | 6891 | 11564 | 3 | 4 | 6 |
| 2005 | 213 | 297 | 519 | 5 | 8 | 14 | 223 | 312 | 544 | 6251 | 8743 | 15268 | 3 | 5 | 8 |
| 2010 | 213 | 397 | 719 | 5 | 11 | 19 | 223 | 417 | 754 | 6251 | 11686 | 21154 | 3 | 7 | 11 |
| **South** | | | | | | | | | | | | | | | |
| 1990 | 68 | 34 | 28 | 2 | 1 | 1 | 72 | 35 | 29 | 2016 | 988 | 813 | 1 | 1 | 0 |
| 1995 | 116 | 34 | 60 | 3 | 1 | 2 | 122 | 35 | 63 | 3427 | 988 | 1754 | 2 | 1 | 1 |
| 2000 | 202 | 66 | 79 | 5 | 2 | 3 | 212 | 69 | 83 | 5958 | 1929 | 2312 | 3 | 2 | 1 |
| 2005 | 202 | 127 | 201 | 5 | 4 | 6 | 212 | 133 | 211 | 5958 | 3729 | 5911 | 3 | 3 | 3 |
| 2010 | 202 | 224 | 395 | 5 | 7 | 11 | 212 | 235 | 415 | 5958 | 6589 | 11631 | 3 | 5 | 6 |
| **East** | | | | | | | | | | | | | | | |
| 1990 | 96 | 0 | 85 | 3 | 0 | 2 | 101 | 0 | 89 | 2826 | 0 | 2501 | 2 | 0 | 1 |
| 1995 | 142 | 0 | 240 | 4 | 0 | 6 | 149 | 0 | 252 | 4181 | 0 | 7065 | 3 | 0 | 4 |
| 2000 | 212 | 0 | 323 | 6 | 0 | 8 | 222 | 0 | 339 | 6242 | 0 | 9507 | 4 | 0 | 5 |
| 2005 | 212 | 58 | 438 | 6 | 2 | 11 | 222 | 61 | 460 | 6242 | 1698 | 12903 | 4 | 1 | 7 |
| 2010 | 212 | 150 | 621 | 6 | 4 | 16 | 222 | 157 | 652 | 6242 | 4396 | 18299 | 4 | 3 | 10 |
| **Northeast** | | | | | | | | | | | | | | | |
| 1990 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 367 | 0 | 0 | 0 |
| 1995 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 367 | 0 | 0 | 0 |
| 2000 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 367 | 0 | 0 | 0 |
| 2005 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 367 | 0 | 0 | 0 |
| 2010 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 367 | 0 | 0 | 0 |

1 · Zone 1, 2 : Zone 2, 3 Zone 3

It can be seen from Table 4.4 that by the year 2005, emissions from thermal power plants in Zone 1 would be similar in all regions except the north-east. In the other two zones, emissions would be the highest in west, with those in the east and south being comparable. Table 4.5 shows the emissions from thermal power plants under the 6% BAU scenario.

**Table 4.5.** Emissions from thermal power plants

(thousand tonnes)
(5 % GDP growth rate)

| | | $SO_x$ | | | CO | | | $NO_x$ | | | TSP | | | HC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| North | | | | | | | | | | | | | | | | |
| | 1990 | 106 | 84 | 36 | 3 | 2 | 1 | 111 | 88 | 38 | 3114 | 2464 | 1073 | 2 | 1 | 1 |
| | 1995 | 122 | 100 | 72 | 3 | 2 | 2 | 128 | 105 | 76 | 3584 | 2934 | 2137 | 2 | 1 | 2 |
| | 2000 | 220 | 164 | 133 | 6 | 3 | 3 | 231 | 172 | 140 | 6465 | 4823 | 3938 | 3 | 2 | 3 |
| | 2005 | 236 | 270 | 331 | 6 | 6 | 8 | 248 | 278 | 338 | 6931 | 7810 | 9500 | 4 | 4 | 6 |
| | 2010 | 248 | 434 | 646 | 6 | 10 | 16 | 260 | 450 | 669 | 7280 | 12609 | 18790 | 4 | 6 | 11 |
| West | | | | | | | | | | | | | | | | |
| | 1990 | 119 | 120 | 141 | 3 | 3 | 4 | 125 | 126 | 148 | 3496 | 3531 | 4150 | 2 | 2 | 2 |
| | 1995 | 135 | 158 | 196 | 3 | 4 | 6 | 142 | 166 | 206 | 3966 | 4651 | 5774 | 2 | 3 | 3 |
| | 2000 | 121 | 133 | 224 | 3 | 3 | 6 | 127 | 140 | 235 | 3563 | 3928 | 6591 | 2 | 2 | 3 |
| | 2005 | 251 | 350 | 612 | 6 | 9 | 17 | 263 | 368 | 642 | 7376 | 10317 | 18016 | 4 | 6 | 9 |
| | 2010 | 264 | 492 | 892 | 6 | 14 | 24 | 277 | 517 | 935 | 7751 | 14491 | 26231 | 4 | 9 | 14 |
| South | | | | | | | | | | | | | | | | |
| | 1990 | 68 | 34 | 28 | 2 | 1 | 1 | 72 | 35 | 29 | 2016 | 988 | 813 | 1 | 1 | 0 |
| | 1995 | 116 | 34 | 60 | 3 | 1 | 2 | 122 | 35 | 63 | 3427 | 988 | 1754 | 2 | 1 | 1 |
| | 2000 | 220 | 72 | 86 | 5 | 2 | 3 | 231 | 75 | 90 | 6494 | 2103 | 2520 | 3 | 2 | 1 |
| | 2005 | 244 | 154 | 243 | 6 | 5 | 7 | 257 | 161 | 255 | 7209 | 4512 | 7152 | 4 | 4 | 4 |
| | 2010 | 259 | 287 | 506 | 6 | 9 | 14 | 271 | 301 | 531 | 7626 | 8434 | 14888 | 4 | 6 | 8 |
| East | | | | | | | | | | | | | | | | |
| | 1990 | 96 | 0 | 85 | 3 | 0 | 2 | 101 | 0 | 89 | 2826 | 0 | 2501 | 2 | 0 | 1 |
| | 1995 | 142 | 0 | 240 | 4 | 0 | 6 | 149 | 0 | 252 | 4181 | 0 | 7065 | 3 | 0 | 4 |
| | 2000 | 235 | 0 | 359 | 7 | 0 | 9 | 246 | 0 | 376 | 6929 | 0 | 10553 | 4 | 0 | 6 |
| | 2005 | 261 | 71 | 539 | 7 | 2 | 14 | 273 | 75 | 566 | 7678 | 2089 | 15871 | 5 | 1 | 9 |
| | 2010 | 276 | 195 | 807 | 8 | 5 | 21 | 289 | 204 | 848 | 8115 | 5715 | 23789 | 5 | 4 | 13 |
| North east | | | | | | | | | | | | | | | | |
| | 1990 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 367 | 0 | 0 | 0 |
| | 1995 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 367 | 0 | 0 | 0 |
| | 2000 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 367 | 0 | 0 | 0 |
| | 2005 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 367 | 0 | 0 | 0 |
| | 2010 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 367 | 0 | 0 | 0 |

1 : Zone 1, 2 : Zone 2, 3 : Zone 3

.2.1.4 Impacts on land : It is estimated that approximately 200 ha of land are required for the disposal of ash from a 210 MW plant (Mathur, 1989a). Based on this, the additional land requirements for ash disposal from new power plants till the year 2010 under both GDP growth rates are given in Table 4.6.

**Table 4.6.** Land requirement for ash disposal for new plants (BAU) in ha

| Region | GDP growth rate | |
|---|---|---|
| | 5% | 6% |
| North | 8242 | 9767 |
| West | 7776 | 9011 |
| South | 6878 | 8222 |
| East | 8010 | 9398 |
| North-east | 0 | 0 |

In Singrauli, out of a total area of 313,183 ha in 1981, arable land occupied 36%, i.e. 113,416 ha. Of this, 18% was cultivable wasteland and 82% of the area was under cultivation. Approximately 1,327 ha was acquired till 1990 for setting up five ash ponds.

.2.1.5 Impact on soil quality: The impact of an operating thermal power plant on the soil environment and in turn on agricultural production could be either due to the direct impact of release of air pollutants (such fly ash) or due to use of agricultural land for siting of plant, transmission corridor and ash ponds.

Fallout estimations from a thermal power plant indicate that 80-90% particle deposition occurs within a 5-10 km radius from the source. Since this deposition of particulate matter goes on all the time, it results in alteration of physico-chemical properties of soils in the vicinity.

Studies have looked at physico-chemical characteristics of garden soils to which various concentrations of fly ash were added (Thakre and Thergaonkar 1985). Water-holding capacity of garden soil is 68.77% while that of fly ash is 52%, showing an 18% reduction. pH does not show any significant variation. Conductivity value for soil is 155 micromhos/cm and increases as the fly ash percentage increases, as compared to 320 micromhos/cm for pure fly ash extract. An increase in percentage of flyash in soils causes a decrease in total exchangeable cation capacity, which is an index of decline in soil fertility.

The operation of coal-based plants brings about changes in trace elements and radio nuclides in soils in the vicinity. Studies have examined alterations in natural radioactivity of soils around certain thermal power plants (Ramachandran et al. 1990). Concentrations of $^{228}Th$, $^{226}Ra$ and $^{40}K$ were determined (relative to countrywide average of natural radioactivity content in soils) in vicinity of the plants and within a 200 km radial distance. Those thermal power plants with a higher capacity would be more likely to have soils with a higher radioactivity content around them, but it would also depend on the age of the plant as well as the natural radioactivity of the soils. Data indicate that there is no relationship between the radial distance from the thermal power plants and soil radioactivity, indicating that fly ash emissions do not modify soils at distant sites to a similar extent. Since soils of a region vary widely, the impact is extremely site specific.

4.2.1.6 Impact on water quality: According to the Central Pollution Control Board, the total wastewater discharge from a thermal power plant can be as high as 100 kl per day per megawatt of power generated. The Biological Oxygen Demand (BOD) in this wastewater can be as high as 150 mg/l. If a 1000 MW plant discharges this large amount of waste water with such a high BOD in a river that has an annual average discharge of 3000 million $m^3$, the increase in BOD of the river water is 1.8 mg/l, which is low. If, however, a cluster of power plants is located in an area that drains into a relatively small river, BOD pollution can be significant. At least three locations in the country could be facing such a problem: the Damodar Valley, the Singrauli region and the National Capital Region. The increased BOD loadings from thermal power plants in these areas could reduce Dissolved Oxygen (DO) in the receiving waters making them unsuitable for aquatic life as well as for other useful purposes. At most other places, as far as BOD is concerned, the impact of thermal power plants on the surrounding water quality would be fairly low.

Damodar valley is a highly stressed area due the combined impacts of coal mining and washing and thermal power generation. In addition, energy intensive industries such as steel and fertilizer are also located in the valley. The BOD concentration in the Damodar river varies between 1.5 and 3.4 mg/l. The average annual flow through the river basin is 12210 million $m^3$. Additional coal mining and power generation are bound to add to the BOD of the river. The Total Suspended Solids (TSS) concentration in the river is similarly high, ranging between 55 and 105 mg/l. Additional power generation

will result in higher TSS concentrations which will exceed the Indian Standard of 100 mg/l. In the Singrauli region, five coal based super-thermal power plants generate over 5000 MW of power. The raw water source for these plants is the Gobind Ballabh Pant Sagar or the Rihand reservoir. The reservoir is also used as a cooling pond for hot water discharges from the five plants, giving rise to thermal pollution. Increased temperature results in a decrease in the DO concentrations, especially in the deeper regions of the reservoir, making them unfit for fish life.

In the National Capital Region, coal-based plants generate about 1500 MW of power. By the year 2000, this figure is expected to be close to 3000 MW. The DO and BOD levels in the river Yamuna are acceptable in Panipat but critical in Delhi. In Delhi, the DO has been as low as 0.8 mg/l and BOD as high as 20 mg/l during the period 1984 to 1988. Although most of this pollution can be attributed to domestic wastewater, additional BOD load on the Yamuna is clearly undesirable regardless of the source.

### 4.2.2 Oil exploration and refining

4.2.2.1 <u>Oil exploration</u>: Other than a potential blow-out, the major source of environmental concern from hydrocarbon exploration and production is the spillage of drilling fluids into the environment.

Table 4.7 provides an estimate of the discharge of drill cuttings and mud chemicals from exploration drilling activity in 1991 and that projected for 2009/10 for the 5% GDP growth rate scenario.

**Table 4.7.** Discharge of drill cuttings and mud chemicals from off-shore exploration and drilling activity

(5% GDP growth rate)

| | (thousand tonnes) | | | |
|---|---|---|---|---|
| Basins | Drill Cuttings | | Chemicals | |
| | 1990/91 | 2009/10 | 1990/91 | 2009/10 |
| K-G | 2.7-4.3 | 4.5-7.2 | 1.2-3.8 | 2.0-6.3 |
| Cauvery | 5.4-8.6 | 2.7-4.3 | 2.4-7.6 | 1.2-3.8 |
| Bengal | 1.8-2.9 | 5.4-8.6 | 0.8-2.5 | 2 4-7.6 |
| K Saurashtra | - | 4.5-7.2 | - | 2.0-6.3 |
| K-K | - | 13.5-21 5 | - | 6.1-19.3 |
| Mahanadi | - | 9.9-15.7 | - | 4.4-14.0 |
| Andaman | - | 3.6-5.7 | - | 1.7-5.1 |
| Bombay | 28.0-44.3 | 61.4-97.2 | 12.6-39.2 | 28.0-86.0 |

It is difficult to quantify the magnitude of the impact from such discharges because the dispersion and dilution of such discharges will vary according to the ambient water condition, composition of drilling fluids and the rates and duration of drilling fluid and cutting discharges. Table 4.7 serves to indicate the magnitude of the problem. It was not possible to measure impacts because of the lack of more detailed baseline data.

At a general level, it can be stated that the extent of impact will depend on the distance of the drilling activity from the coast. For example, most of the activity occurring in Bombay High is at a distance of 66 km from the coast and hence little impact would be felt on the coast from such discharges. Adverse impacts on water column organisms are expected to be minor and of short duration. Effects on sessile organisms is limited to a short distance from a discharge point.

If drilling activity is closer to the coast as for example in Palk Bay or is close to major estuaries/deltas, then the impacts will tend to be more significant as the extent of dispersion and dilution of the discharges will be limited.

4.2.2.2 <u>Oil refineries</u>: A comparison of TSP, $SO_x$ and $NO_x$ emitted from a typical refinery (6 MT) and a 1000 MW coal based power plant shows negligible TSP emissions along with lower levels of $SO_x$ and $NO_x$. Therefore, a refinery by itself will not significantly affect air quality, a conclusion also observed in studies conducted for a refinery located at Mathura (Centre for Science and Environment, 1985). However, if located in an already polluted zone, the impacts will be significant. Refineries operating today are spread over the five regions with roughly half of them located in Zone 1 areas, one-third in Zone 2 and the remaining one-sixth of capacity in Zone 3. It is assumed that all future refineries after the year 2000 will be located in Zone 2 (one-third of capacity) and Zone 3 (the remaining two-third of capacity).

Emissions from refineries for the BAU strategy are given in Table 4.8 for the 5% scenario. Since refinery capacity remains the same under the 6% scenario, the emissions also remain the same.

The discharge of refinery effluents has a significant adverse impact on the receiving water body. A typical refinery (6 MT/annum) discharging into a river of 400 bcm flow will increase the BOD by approximately 1.5 mg/l. In comparison, a 1000 MW coal based plant at the same location would have an impact that would approximately be lower by an order of magnitude.

The two largest refineries in India, Koyali and Mathura, process 9.5 and 7.5 MT of crude per year respectively. While

the Mathura refinery will increase the BOD in the Yamuna by 4.15 mg/l, the Koyali refinery will raise the BOD in the Narmada by 2.1 mg/l. Since the magnitude of impact depends largely on the characteristics of the receiving water body, it is difficult to extend the analysis to new refineries being planned under the BAU strategy, given the absence of information on their siting.

**Table 4.8.** Emissions from oil refineries (tonnes)

(Tonnes)

| | $SO_x$ | | | CO | | | $NO_x$ | | | TSP | | | HC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| North | | | | | | | | | | | | | | | |
| 1990 | 0 | 190 | 0 | 0 | 37 | 0 | 0 | 1330 | 0 | 0 | 3 | 0 | 0 | 9383 | 0 |
| 1995 | 0 | 190 | 152 | 0 | 37 | 28 | 0 | 1330 | 1064 | 0 | 3 | 2 | 0 | 9383 | 7506 |
| 2000 | 0 | 223 | 219 | 0 | 43 | 40 | 0 | 1561 | 1533 | 0 | 3 | 3 | 0 | 11013 | 10816 |
| 2005 | 0 | 262 | 299 | 0 | 51 | 55 | 0 | 1838 | 2095 | 0 | 3 | 4 | 0 | 12967 | 14782 |
| 2010 | 0 | 317 | 411 | 0 | 61 | 75 | 0 | 2226 | 2882 | 0 | 4 | 5 | 0 | 15702 | 20336 |
| West | | | | | | | | | | | | | | | |
| 1990 | 481 | 0 | 0 | 97 | 0 | 0 | 3369 | 0 | 0 | 4 | 0 | 0 | 23771 | 0 | 0 |
| 1995 | 481 | 0 | 0 | 97 | 0 | 0 | 3369 | 0 | 0 | 4 | 0 | 0 | 23771 | 0 | 0 |
| 2000 | 481 | 33 | 67 | 97 | 6 | 12 | 3369 | 231 | 469 | 4 | 0 | 1 | 23771 | 1630 | 3309 |
| 2005 | 481 | 72 | 147 | 97 | 13 | 27 | 3369 | 508 | 1031 | 4 | 1 | 2 | 23771 | 3584 | 7276 |
| 2010 | 481 | 128 | 259 | 97 | 23 | 48 | 3369 | 896 | 1818 | 4 | 2 | 3 | 23771 | 6319 | 12830 |
| South | | | | | | | | | | | | | | | |
| 1990 | 114 | 142 | 114 | 37 | 22 | 37 | 798 | 993 | 798 | 1 | 1 | 3 | 5630 | 7006 | 5630 |
| 1995 | 114 | 142 | 190 | 37 | 22 | 51 | 798 | 993 | 1330 | 1 | 1 | 4 | 5630 | 7006 | 9383 |
| 2000 | 114 | 174 | 257 | 37 | 28 | 63 | 798 | 1224 | 1799 | 1 | 2 | 4 | 5630 | 8636 | 12693 |
| 2005 | 114 | 214 | 337 | 37 | 36 | 78 | 798 | 1501 | 2361 | 1 | 2 | 5 | 5630 | 10590 | 16659 |
| 2010 | 114 | 269 | 449 | 37 | 46 | 99 | 798 | 1889 | 3148 | 1 | 3 | 7 | 5630 | 13325 | 22213 |
| East | | | | | | | | | | | | | | | |
| 1990 | 69 | 83 | 0 | 0 | 0 | 0 | 488 | 585 | 0 | 1 | 2 | 0 | 3440 | 4128 | 0 |
| 1995 | 69 | 83 | 0 | 0 | 0 | 0 | 488 | 585 | 0 | 1 | 2 | 0 | 3440 | 4128 | 0 |
| 2000 | 69 | 116 | 67 | 0 | 6 | 12 | 488 | 816 | 469 | 1 | 2 | 1 | 3440 | 5758 | 3309 |
| 2005 | 69 | 156 | 147 | 0 | 13 | 27 | 488 | 1093 | 1031 | 1 | 3 | 2 | 3440 | 7712 | 7276 |
| 2010 | 69 | 211 | 259 | 0 | 23 | 48 | 488 | 1481 | 1818 | 1 | 3 | 3 | 3440 | 10447 | 12830 |
| North-east | | | | | | | | | | | | | | | |
| 1990 | 0 | 0 | 68 | 0 | 0 | 0 | 0 | 0 | 479 | 0 | 0 | 1 | 0 | 0 | 3378 |
| 1995 | 0 | 0 | 144 | 0 | 0 | 14 | 0 | 0 | 1011 | 0 | 0 | 2 | 0 | 0 | 7131 |
| 2000 | 0 | 0 | 244 | 0 | 0 | 32 | 0 | 0 | 1711 | 0 | 0 | 3 | 0 | 0 | 12070 |
| 2005 | 0 | 0 | 363 | 0 | 0 | 54 | 0 | 0 | 2550 | 0 | 0 | 4 | 0 | 0 | 17990 |
| 2010 | 0 | 0 | 531 | 0 | 0 | 85 | 0 | 0 | 3725 | 0 | 0 | 6 | 0 | 0 | 26280 |

1 Zone 1, 2 Zone 2, 3 Zone 3

### 4.2.3 Hydropower

Of the nearly 50,000 MW of installed capacity that will be added in the next 20 years, approximately 95% will be in medium and large size dams and therefore may have the potential for causing considerable environmental and social impacts. The remaining 5% will be created by small dams that will not lead to any major environmental disruption.

These environmental and social impacts are a direct result of dam construction and the consequent formation of a reservoir. Among the impacts, the significant ones include displacement of people, submergence of agricultural and forest land, increased seismic activity leading to a dam failure and the prevalence of water-borne diseases.

Table 4.9 shows the extent of submergence of forests and displacement of people for 29 dams that have been sanctioned and are included in the BAU strategy. These dams constitute nearly 35% of the installed capacity.

The data clearly show the large variation that exists in the relationship between the installed capacity and the submergence of forests and displacement of people. The impacts are extremely site specific. For instance, forest submergence varies from 0.01 ha/MW in the case of Teesta (1200 MW) and Maneri (304 MW) to 22.45 ha/MW for the Narmada and Sardar Sarovar Project (2450 MW). Similarly, displacement too shows a very large variation ranging from no displacement as in the case of Srisailam (990 MW) to 288 people/MW as in the case of Bansagar (348 MW). Hence, it is extremely difficult to extend the analysis of environmental impacts to dams where site specific details are not available (remaining 65% of capacity).

The most immediate social impact of large dams is large scale displacement of people. The oustees lose their houses, land, property and other tangible assets. Although compensation is given, the problem of implementation, and in some cases the rehabilitation package by itself, fail to adequately compensate the oustees. Moreover, as past records show, when oustees are rehabilitated, they are almost never moved <u>en block</u> but are scattered, thus making it more difficult for them to re-establish their community life. Of the 16,000 families that were displaced because of the Pong dam in the hills of Himachal Pradesh, 6000 families were given land in the command area of Indira Gandhi Canal in the Rajasthan desert, which was a complete change of cultural and climatic environment for the oustees. The issue of rehabilitation becomes more serious when the number of displaced people is very large as in the case of Narmada and Sardar Sarovar projects, where 300,000 people are to be ousted from their homelands.

**Table 4.9.** Submergence and displacement in dam sites

| Region | Capacity (MW) | Displacement (No.of people) | Forest submerged (ha) | Affected forest type |
|---|---|---|---|---|
| **NORTH** | | | | |
| Salal | 345 | - | 0 | STDE |
| Chamera | 540 | - | 785 | TDD |
| Dhauliganga | 280 | 550 | 19.2 | TDD |
| Sawalkot | 600 | 2460 | 165.5 | STDE |
| Uri | 480 | 1070 | 0 | STP |
| Dulhasti | 390 | 0 | 0 | STDE |
| Baglihar | 450 | 1370 | 12.82 | STDE |
| Thein | 600 | 9595 | 852 | TDD |
| Srinagar | 330 | 0 | 202.84 | STP |
| Vishnuprayag | 480 | 0 | 80 | HMT |
| Lakwarvyasi | 420 | 3502 | 699 | TDD |
| Maneri 2 | 304 | 150 | 2 | HMT |
| Naphtajhakri | 1500 | 750 | 0 | STP |
| Kohl | 800 | 2652 | 989.3 | STP |
| Tehri | 1000 | 46000 | 1600 | STP |
| Kishau | 600 | 2403 | 3031 | STP |
| **WEST** | | | | |
| Bansagar | 348 | 100000 | 4478 | TMD |
| Koyna stg IV | 1000 | 0 | 80 | TMD |
| Narmada& | | | | TMD |
| S.Sarovar | 2450 | 300000 | 55000 | TMD |
| Hasdeobango | 120 | 12500 | 10250 | TMD |
| Ghatghar | 250 | 300 | 91 | TMD |
| **SOUTH** | | | | |
| Srisailam | 990 | 0 | 0 | TDD |
| Kalinadi | 270 | 1979 | 1214.5 | TMD |
| Puyankutty | 240 | 87 | 1900 | TMD |
| **EAST** | | | | |
| Ramman | 50 | 600 | 0 | TMD |
| Koel karo | 710 | 25000 | 1003 | TMD |
| Upper indra-vati | 600 | 17500 | 708 | TMD |
| **NORTH-EAST** | | | | |
| Rangit | 60 | 225 | 6.5 | MWT |
| Teesta | 1200 | 40 | 12 | MWT |

STDE: Sub-tropical Dry Evergreen; STP: Sub-tripical pine; TDD: Tropical Dry Deciduous; TMD: Tropical Moist Deciduous; HMT: Himalayan Moist Temperate; MWT: Montane Wet Temperate.

Loss of forests implies a loss of all benefits that a forest provides e.g. prevention of soil erosion, production of oxygen, recycling of water and controlling humidity, absorption of carbon dioxide and sheltering of birds. The largest submergence of forests is seen in the Narmada Sagar, Hasdeobango, Tehri and Kishau dams. The large quantity of water impounded in the reservoir increases the local mass and the pressure thus created may be enough to increase or initiate seismic activity near the dam area. Earthquakes can cause a dam to collapse and cause further devastation downstream. However, most dams are designed to withstand earthquakes. In India, out of more than 1800 large dams, only two, Koyna and Bhatsa in Maharashtra, are known to have experienced earthquakes. The earthquake in Koyna in 1967 was more significant (6.7 on the Richter scale against 4.5 in the case of Bhatsa dam). The Koyna earthquake claimed 200 lives and injured 1500 people. The Tehri dam lies in a region of high seismic potential. A failure of the dam would be catastrophic, especially considering the fact that a densely populated area lies downstream. The earthquake that occurred in Uttarkashi (a neighbouring district) in October 1991 stresses the need to re-examine the safety of the dam.

## 4.3 Environmental impacts of energy use

### 4.3.1 Industrial Sector

The major pollutants from industries have their source in process wastes. However, for the purpose of this study, only air pollution resulting from the combustion of various fuels has been considered. The industries that were examined for their pollution potential are as follows: textile, chemical and petrochemical, aluminium, iron and steel, mini-steel, cement, fertilizer, paper, sponge iron and machinery. Estimates of high speed diesel, light diesel oil, fuel oil, low stock high sulphur fuel, coal, naphtha, natural gas and petroleum products to be used in the industrial sector are those given in Chapter 2.

It was assumed that all iron, steel and cement units are located in the critical zone (Zone 1). Aluminium and paper units have been located in Zone 3. Fertilizer plants are usually sited in locations that correspond to Zone 2. Chemical and petrochemical plants are located by and large in the west and east. We have assumed that no such unit will be located in Zone 1 and that the capacities will be distributed in the ratio 1:2 in Zone 2 and Zone 3. Tables 4.10 and 4.11

show emissions from the industrial sector for the 5 and 6% scenarios respectively.

**Table 4.10.** Emissions from the industrial Sector

(5% GDP growth rate)

| | sox(000t) | | | co(000t) | | | nox(000t) | | | tsp(000t) | | | hc(000t) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| north | | | | | | | | | | | | | | | |
| 1990 | 41 | 4 | 27 | 1 | 0 | 1 | 36 | 1 | 18 | 929 | 1 | 241 | 0 | 0 | 0 |
| 1995 | 58 | 5 | 37 | 2 | 0 | 1 | 52 | 3 | 25 | 1324 | 1 | 338 | 0 | 0 | 0 |
| 2000 | 77 | 8 | 35 | 2 | 0 | 1 | 70 | 3 | 23 | 1790 | 2 | 201 | 0 | 0 | 0 |
| 2005 | 105 | 11 | 40 | 3 | 0 | 1 | 95 | 5 | 28 | 2435 | 3 | 211 | 0 | 0 | 0 |
| 2010 | 143 | 16 | 47 | 4 | 0 | 1 | 129 | 7 | 35 | 3316 | 4 | 223 | 0 | 0 | 0 |
| west | | | | | | | | | | | | | | | |
| 1990 | 149 | 26 | 34 | 4 | 1 | 1 | 134 | 9 | 25 | 3454 | 7 | 390 | 0 | 0 | 0 |
| 1995 | 206 | 42 | 46 | 5 | 1 | 1 | 186 | 21 | 33 | 4810 | 153 | 484 | 0 | 0 | 0 |
| 2000 | 248 | 59 | 42 | 6 | 1 | 1 | 223 | 34 | 30 | 5728 | 340 | 306 | 0 | 0 | 0 |
| 2005 | 319 | 78 | 46 | 8 | 2 | 1 | 287 | 45 | 36 | 7352 | 434 | 329 | 0 | 0 | 0 |
| 2010 | 407 | 106 | 53 | 10 | 2 | 1 | 366 | 63 | 43 | 9314 | 554 | 355 | 0 | 0 | 0 |
| south | | | | | | | | | | | | | | | |
| 1990 | 121 | 7 | 24 | 3 | 0 | 1 | 115 | 2 | 17 | 3067 | 2 | 298 | 0 | 0 | 0 |
| 1995 | 162 | 14 | 33 | 4 | 0 | 1 | 153 | 8 | 23 | 4079 | 103 | 380 | 0 | 0 | 0 |
| 2000 | 212 | 18 | 36 | 5 | 0 | 1 | 202 | 10 | 24 | 5361 | 104 | 334 | 0 | 0 | 0 |
| 2005 | 256 | 24 | 43 | 7 | 1 | 1 | 242 | 14 | 28 | 6393 | 134 | 364 | 0 | 0 | 0 |
| 2010 | 335 | 34 | 54 | 9 | 1 | 1 | 315 | 20 | 35 | 8291 | 169 | 397 | 0 | 0 | 0 |
| east | | | | | | | | | | | | | | | |
| 1990 | 198 | 3 | 10 | 5 | 1 | 1 | 192 | 8 | 8 | 5178 | 6 | 161 | 0 | 0 | 0 |
| 1995 | 222 | 49 | 15 | 6 | 1 | 1 | 216 | 14 | 12 | 5828 | 183 | 245 | 0 | 0 | 0 |
| 2000 | 236 | 60 | 15 | 6 | 1 | 1 | 224 | 35 | 12 | 5979 | 588 | 220 | 0 | 0 | 0 |
| 2005 | 270 | 84 | 17 | 7 | 2 | 1 | 252 | 47 | 13 | 6651 | 752 | 232 | 0 | 0 | 0 |
| 2010 | 325 | 116 | 20 | 8 | 3 | 1 | 298 | 63 | 16 | 7795 | 964 | 246 | 0 | 0 | 0 |
| northeast | | | | | | | | | | | | | | | |
| 1990 | 2 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 25 | 0 | 15 | 0 | 0 | 0 |
| 1995 | 2 | 1 | 6 | 0 | 0 | 0 | 2 | 0 | 5 | 37 | 0 | 107 | 0 | 0 | 0 |
| 2000 | 3 | 1 | 6 | 0 | 0 | 0 | 2 | 0 | 5 | 54 | 0 | 88 | 0 | 0 | 0 |
| 2005 | 4 | 2 | 6 | 0 | 0 | 0 | 3 | 1 | 5 | 76 | 0 | 82 | 0 | 0 | 0 |
| 2010 | 6 | 2 | 6 | 0 | 0 | 0 | 5 | 1 | 5 | 104 | 1 | 77 | 0 | 0 | 0 |

1 Zone 1, 2 Zone 2, 3 Zone 3

**Table 4.11.** Emissions from the industrial sector

(thousand tonnes)

(6% GDP growth rate)

| | | sox(000t) | | | co(000t) | | | nox(000t) | | | tsp(000t) | | | hc(000t) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| north | | | | | | | | | | | | | | | | |
| | 1990 | 41 | 4 | 27 | 1 | 0 | 1 | 36 | 1 | 18 | 929 | 1 | 241 | 0 | 0 | 0 |
| | 1995 | 53 | 5 | 35 | 1 | 0 | 1 | 46 | 1 | 23 | 1191 | 1 | 309 | 0 | 0 | 0 |
| | 2000 | 67 | 7 | 44 | 2 | 0 | 2 | 59 | 2 | 30 | 1528 | 2 | 396 | 0 | 0 | 0 |
| | 2005 | 86 | 8 | 57 | 2 | 0 | 2 | 76 | 2 | 38 | 1959 | 2 | 508 | 0 | 0 | 0 |
| | 2010 | 111 | 11 | 73 | 3 | 0 | 3 | 97 | 3 | 49 | 2512 | 3 | 652 | 0 | 0 | 0 |
| west | | | | | | | | | | | | | | | | |
| | 1990 | 149 | 26 | 34 | 4 | 1 | 1 | 134 | 9 | 25 | 3454 | 7 | 390 | 0 | 0 | 0 |
| | 1995 | 191 | 33 | 44 | 5 | 1 | 1 | 172 | 12 | 32 | 4429 | 9 | 500 | 0 | 0 | 0 |
| | 2000 | 245 | 43 | 56 | 7 | 2 | 2 | 220 | 15 | 41 | 5680 | 12 | 641 | 0 | 0 | 0 |
| | 2005 | 314 | 55 | 72 | 8 | 2 | 2 | 283 | 19 | 53 | 7284 | 15 | 822 | 0 | 0 | 0 |
| | 2010 | 403 | 70 | 92 | 11 | 3 | 3 | 362 | 24 | 68 | 9341 | 19 | 1055 | 0 | 0 | 0 |
| south | | | | | | | | | | | | | | | | |
| | 1990 | 121 | 7 | 24 | 3 | 0 | 1 | 115 | 2 | 17 | 3067 | 2 | 298 | 0 | 0 | 0 |
| | 1995 | 155 | 9 | 31 | 4 | 0 | 1 | 147 | 3 | 22 | 3933 | 3 | 382 | 0 | 0 | 0 |
| | 2000 | 199 | 12 | 39 | 5 | 0 | 2 | 189 | 3 | 28 | 5044 | 3 | 490 | 0 | 0 | 0 |
| | 2005 | 255 | 15 | 51 | 6 | 0 | 2 | 243 | 4 | 36 | 6468 | 4 | 628 | 0 | 0 | 0 |
| | 2010 | 327 | 19 | 65 | 8 | 0 | 3 | 311 | 5 | 46 | 8294 | 5 | 806 | 0 | 0 | 0 |
| east | | | | | | | | | | | | | | | | |
| | 1990 | 198 | 3 | 10 | 5 | 1 | 1 | 192 | 8 | 8 | 5178 | 6 | 161 | 0 | 0 | 0 |
| | 1995 | 254 | 4 | 13 | 6 | 1 | 1 | 246 | 10 | 10 | 6640 | 8 | 206 | 0 | 0 | 0 |
| | 2000 | 326 | 5 | 16 | 8 | 2 | 2 | 316 | 13 | 13 | 8515 | 10 | 265 | 0 | 0 | 0 |
| | 2005 | 418 | 6 | 21 | 11 | 2 | 2 | 405 | 17 | 17 | 10920 | 13 | 340 | 0 | 0 | 0 |
| | 2010 | 535 | 8 | 27 | 14 | 3 | 3 | 519 | 22 | 22 | 14003 | 16 | 435 | 0 | 0 | 0 |
| northeast | | | | | | | | | | | | | | | | |
| | 1990 | 2 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 25 | 0 | 15 | 0 | 0 | 0 |
| | 1995 | 3 | 1 | 3 | 0 | 0 | 0 | 1 | 0 | 1 | 32 | 0 | 19 | 0 | 0 | 0 |
| | 2000 | 3 | 2 | 3 | 0 | 0 | 0 | 2 | 0 | 2 | 41 | 0 | 25 | 0 | 0 | 0 |
| | 2005 | 4 | 2 | 4 | 0 | 0 | 0 | 2 | 0 | 2 | 53 | 0 | 32 | 0 | 0 | 0 |
| | 2010 | 5 | 3 | 5 | 0 | 0 | 0 | 3 | 0 | 3 | 68 | 0 | 41 | 0 | 0 | 0 |

1 Zone 1, 2 . Zone 2, 3 · Zone 3

It is seen that emissions from industries are the highest in the west. East and south have somewhat similar emissions levels.

### 4.3.2 Transport sector

The most widespread and significant impacts of oil

utilization come from mobile sources. With the sharp increase in the number of motorcycles, scooters, automobiles, vans, trucks and buses, this sector has become the largest contributor to the deterioration in air quality in urban settlements. In Bombay, Delhi and Calcutta, on an average, vehicular emissions account for around fifty per cent of all oxides of nitrogen and about thirty percent of all particulate emissions. The major share is contributed by heavy duty diesel vehicles (trucks and buses) and by two stroke engine vehicles (scooters, motorcycles, mopeds and auto-rickshaws) (Mathur, 1989 b).

Emissions were determined by the product of per capita emissions and population for each zone in all the regions. Per capita emissions for each zone were estimated by taking a representative urban conglomeration and its travel demand. It is difficult to estimate a different set of figures for the 5% and 6% scenarios since on one hand higher GDP results in greater travel demand (passenger kilometers and tonne kilometers) while a lower population (associated with the 6% GDP scenarios) would tend to lower the travel demand. The emissions from the transport sector are presented in Table 4.12 and can be considered as representative loadings for both the scenarios.

3.3 Domestic non-commercial sector

In literature, deforestation has been defined in several distinct ways, e.g. transformation of primary closed forests to any other formations; loss of any kind of closed forest; and loss of forest land (Allen and Barnes, 1985; Meyers, 1980; FAO/UNEP, 1982 a & b; FAO, 1980).

It is, therefore, clear that the precise definition of deforestation must first be specified. Attributing causes for deforestation can only follow such an exercise. Take, for example, the hypothesized link between firewood use in rural areas and deforestation. If either of the first two definitions are followed, studies in the past (such as the NCAER survey is 1979) indicate that rural energy use is very **rarely** responsible for any deforestation since a large fraction of the woody biomass used is in the form of twigs. If, on the other hand, the third definition were to be followed, deforestation and rural energy use would have much closer links. The third definition incorporates a much wider definition of forests. The use of woody biomass in urban areas can more often be linked to deforestation than rural energy consumption. Surveys in cities indicate that the need for lower transportation costs leads to a better variety of

woody biomass (essentially logs, but not thick enough to have timber value).

**Table 4.12.** Emissions from the transport sector

(thousand tonnes)

| | $SO_x$ | | | CO | | | $NO_x$ | | | TSP | | | HC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| North | | | | | | | | | | | | | | | |
| 1990 | 12 | 1 | 31 | 299 | 53 | 1673 | 72 | 9 | 187 | 6 | 1 | 34 | 109 | 22 | 870 |
| 1995 | 15 | 2 | 29 | 416 | 67 | 2212 | 94 | 10 | 174 | 8 | 1 | 42 | 151 | 28 | 1218 |
| 2000 | 20 | 2 | 43 | 559 | 96 | 3568 | 121 | 11 | 197 | 10 | 2 | 69 | 206 | 42 | 2046 |
| 2005 | 39 | 2 | 52 | 842 | 132 | 5288 | 165 | 13 | 257 | 15 | 2 | 104 | 306 | 69 | 2659 |
| 2010 | 35 | 3 | 62 | 1223 | 199 | 8380 | 218 | 16 | 282 | 22 | 4 | 149 | 449 | 119 | 3941 |
| West | | | | | | | | | | | | | | | |
| 1990 | 17 | 2 | 23 | 426 | 62 | 1223 | 103 | 11 | 137 | 8 | 1 | 25 | 155 | 25 | 636 |
| 1995 | 21 | 2 | 21 | 580 | 84 | 1640 | 130 | 12 | 129 | 11 | 2 | 32 | 211 | 35 | 902 |
| 2000 | 27 | 3 | 22 | 751 | 138 | 2418 | 162 | 17 | 133 | 14 | 3 | 47 | 276 | 61 | 1386 |
| 2005 | 51 | 3 | 34 | 1104 | 210 | 3495 | 216 | 21 | 170 | 20 | 4 | 70 | 401 | 109 | 1757 |
| 2010 | 44 | 5 | 33 | 1552 | 362 | 4501 | 277 | 29 | 152 | 27 | 7 | 80 | 570 | 216 | 2117 |
| South | | | | | | | | | | | | | | | |
| 1990 | 1 | 3 | 26 | 21 | 100 | 1402 | 5 | 17 | 157 | 0 | 2 | 28 | 8 | 40 | 729 |
| 1995 | 1 | 3 | 24 | 31 | 129 | 1841 | 7 | 19 | 145 | 1 | 2 | 36 | 11 | 54 | 1013 |
| 2000 | 2 | 4 | 26 | 43 | 195 | 2808 | 9 | 23 | 155 | 1 | 4 | 54 | 16 | 85 | 1610 |
| 2005 | 3 | 5 | 40 | 68 | 277 | 4033 | 13 | 27 | 196 | 1 | 5 | 80 | 25 | 144 | 2028 |
| 2010 | 3 | 6 | 46 | 102 | 435 | 6218 | 18 | 35 | 210 | 2 | 9 | 111 | 38 | 260 | 2925 |
| East | | | | | | | | | | | | | | | |
| 1990 | 12 | 1 | 24 | 289 | 23 | 1283 | 70 | 4 | 144 | 6 | 0 | 26 | 105 | 9 | 667 |
| 1995 | 14 | 1 | 22 | 379 | 32 | 1701 | 85 | 5 | 134 | 7 | 1 | 33 | 138 | 13 | 937 |
| 2000 | 16 | 1 | 25 | 464 | 54 | 2674 | 101 | 7 | 147 | 9 | 1 | 52 | 171 | 24 | 1533 |
| 2005 | 30 | 1 | 39 | 659 | 83 | 3920 | 129 | 8 | 191 | 12 | 2 | 78 | 239 | 43 | 1971 |
| 2010 | 25 | 2 | 45 | 887 | 142 | 6129 | 158 | 11 | 207 | 16 | 3 | 109 | 326 | 84 | 2883 |
| North-east | | | | | | | | | | | | | | | |
| 1990 | | | 5 | | | 238 | | | 27 | | | 5 | | | 124 |
| 1995 | | | 4 | | | 331 | | | 26 | | | 6 | | | 182 |
| 2000 | | | 5 | | | 505 | | | 28 | | | 10 | | | 289 |
| 2005 | | | 7 | | | 754 | | | 36 | | | 15 | | | 379 |
| 2010 | | | 9 | | | 1214 | | | 41 | | | 22 | | | 571 |

1 Zone 1, 2 Zone 2, 3 Zone 3

Based on the fuelwood demands presented in Table 2.19 (Chapter 2, Section 2.2) and sustainable yields in Table 1.14 (Chapter 1, Section 2.5.1), the approximate level of pressure on forest resources is presented in Table 4.13.

**Table 4.13.** The level of pressure on forests because of fuelwood requirements

| | Degree of shortage | | | | |
|---|---|---|---|---|---|
| | 1991 | 1995 | 2000 | 2005 | 2010 |
| EASTERN | | | | | |
| Bihar | severe | severe | severe | severe | severe |
| Orissa | none | none | none | none | sign |
| West Bengal | severe | severe | severe | severe | severe |
| NORTHERN | | | | | |
| Gujarat | severe | severe | severe | severe | severe |
| Haryana | severe | severe | severe | severe | severe |
| Himachal Pradesh | none | none | none | sign | sign. |
| Jammu & Kashmir | surplus | surplus | none | none | none |
| Punjab | severe | severe | severe | severe | severe |
| Uttar Pradesh | severe | severe | severe | severe | severe |
| NORTHEASTERN | | | | | |
| Arunachal Pradesh | surplus | surplus | surplus | surplus | surplus |
| Assam | sign | sign | major | major | major |
| Manipur | surplus | surplus | surplus | surplus | surplus |
| Meghalaya | surplus | surplus | surplus | surplus | surplus |
| Mizoram | surplus | surplus | surplus | surplus | surplus |
| Nagaland | surplus | surplus | surplus | surplus | surplus |
| Sikkim | surplus | surplus | surplus | surplus | surplus |
| Tripura | none | none | sign | sign | sign |
| SOUTHERN | | | | | |
| Andhra Pradesh | major | major | severe | severe | severe |
| Karnataka | major | major | major | major | severe |
| Kerala | severe | severe | severe | severe | severe |
| Tamil Nadu | severe | severe | severe | severe | severe |
| WESTERN | | | | | |
| Goa, Damand and Diu | sign | none | none | none | none |
| Madhya Pradesh | none | none | none | none | none |
| Maharashtra | major | severe | severe | severe | severe |
| Rajasthan | severe | severe | severe | severe | severe |

sign significant

Generalizing sustainable yield from forests (natural or man-made) is difficult. Sustainable yields depend on a wide range of factors, e.g. from quality of land, the species planted, the nature of wood removal, etc. There is no

conclusive average sustainable fuelwood yield. The National Commission on Agriculture (NCA) in its report found that the recorded firewood removal in the period 1965-70 was high (0.61 t/ha/y) in U.P. and the national average was 0.13 t/ha/y. It also felt that the recorded removals accounted for not more than 10 per cent of total removal, thereby implying a productivity of about 6.1 t/ha/y for U.P. and the national average of about 1.3 t/ha/y. The Advisory Board on Energy quotes a World Bank appraisal report on expected yields from some social forestry projects. The expected yields, according to this report, range from a low of 0.9 t/ha/y for 'Babul' tree plantation on average land to a high of 14.4 t/ha/y for Leucaena species planted on irrigated land along canals. Another report indicates that the present productivity is a mere 4 per cent of the potential and that with proper management, the productivity of 4-8 t/ha/y is realizable.

Clearly, no estimates of either the sustainable yield or the contribution of forest resources to the total firewood and/or wood demand, **at the macro level**, can be defended with much rigour. These are, at best, rough estimates and should be treated as such. The situation will remain the same under both scenarios.

## 4.4 Carbon dioxide emissions from energy production and use

Anthropogenic emissions are substantially increasing the atmospheric concentrations of greenhouse gases (carbon dioxide, methane, chloroflurocarbons and nitrous oxide). The Intergovernment Panel on Climate Change (IPCC) has estimated that $CO_2$ is responsible for approximately 61% of the increases in radiative forcing due to increased concentrations of GHGs since pre-industrial times. Table 4.14 shows $CO_2$ emissions for both the scenarios.

It is estimated that total $CO_2$ emissions increase at an annual average rate of roughly 4.8 per cent per annum over the period 1990-2010. Although coal accounts for the maximum emissions in absolute terms under the BAU scenario, emissions from natural gas increase at the fastest rate. At the level of individual sectors, the power sector makes the greatest contribution to $CO_2$ emissions followed by industry.

**Table 4.14.** $CO_2$ Emissions for the BAU scenario (million tonnes)

| Region | Year | 5% GDP growth rate | | | 6% GDP growth rate | | |
|---|---|---|---|---|---|---|---|
| | | Coal | Oil | Nat Gas | Coal | Oil | Nat Gas |
| North | | | | | | | |
| | 1990 | 28 | 12 | 3 | 28 | 12 | 3 |
| | 1995 | 29 | 19 | 4 | 29 | 20 | 4 |
| | 2000 | 38 | 25 | 6 | 40 | 27 | 7 |
| | 2005 | 50 | 33 | 7 | 56 | 35 | 8 |
| | 2010 | 69 | 43 | 8 | 82 | 47 | 10 |
| West | | | | | | | |
| | 1990 | 47 | 12 | 3 | 47 | 12 | 3 |
| | 1995 | 50 | 20 | 5 | 51 | 21 | 5 |
| | 2000 | 60 | 26 | 9 | 64 | 28 | 8 |
| | 2005 | 74 | 33 | 10 | 83 | 35 | 11 |
| | 2010 | 94 | 42 | 14 | 112 | 46 | 15 |
| South | | | | | | | |
| | 1990 | 30 | 9 | 1 | 30 | 9 | 1 |
| | 1995 | 30 | 15 | 1 | 31 | 15 | 2 |
| | 2000 | 40 | 19 | 2 | 44 | 20 | 3 |
| | 2005 | 52 | 24 | 3 | 61 | 33 | 3 |
| | 2010 | 71 | 31 | 5 | 89 | 33 | 5 |
| East | | | | | | | |
| | 1990 | 37 | 7 | 0 | 37 | 7 | 0 |
| | 1995 | 41 | 11 | 0 | 41 | 11 | 0 |
| | 2000 | 48 | 15 | 1 | 50 | 15 | 1 |
| | 2005 | 58 | 19 | 1 | 62 | 20 | 1 |
| | 2010 | 74 | 25 | 1 | 83 | 25 | 1 |
| North-east | | | | | | | |
| | 1990 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 1995 | 1 | 2 | 1 | 1 | 2 | 1 |
| | 2000 | 1 | 2 | 2 | 1 | 2 | 3 |
| | 2005 | 1 | 3 | 3 | 1 | 3 | 4 |
| | 2010 | 2 | 4 | 5 | 1 | 4 | 6 |

Nat Gas Natural Gas

## 4.5 Location specific environmental impacts

### 4.5.1 Singrauli Region

Singrauli straddles the border between the states of Madhya Pradesh and Uttar Pradesh in Central India and covers a total area of about 313 183 ha. In 1981, land use was divided among forests (35%), arable land (36%), Rihand reservoir (14%) and area not available for cultivation (15%). Since 1981, the

overall land use pattern has undergone considerable changes following large scale concentration of economic activities such as coal mining and power generation, particularly in the area around the reservoir. Coal is by far the most significant mineral of this area. The Singrauli Coalfield extends over an area of 2200 sq.km. and has an estimated coal reserves of 10850 MT as detailed below in Table 4.15.

**Table 4.15.** Coal reserves of Singrauli coalfield

(million tonnes)

| Category | Upto 300 m depth | 300 m - 600 m depth | Total |
|---|---|---|---|
| Proved | 3801 | 28 | 3829 |
| Indicated | 1245 | 76 | 1321 |
| Inferred | 1405 | 4295 | 5700 |
| Total | 6451 | 4399 | 10850 |

**Source:** Environmental Study of the Singrauli Area, Synthesis Report (March 1991), NTPC.

4.5.1.1 <u>Land use pattern</u>: The land use pattern in the core industrial area is given in Table 4.16.

**Table 4.16.** Land use pattern in the core area

| Land use | Area covered (ha) | Percent share |
|---|---|---|
| Power Plants | | |
| Plant | 1040.0 | 2.2 |
| Ash dykes | 4500.0 | 9.4 |
| Power transmission corridor | 14428.0 | 30 1 |
| Sub-total | 19968.0 | 41.7 |
| Coal Mines | | |
| Mining block | 14905.0 | 31.1 |
| Infrastructure | 3319.0 | 6.9 |
| Spoil dumps | 732.0 | 1.5 |
| Sub-Total | 18956.0 | 39.5 |
| Other Industrial Area | 1737.0 | 3.8 |
| Total | 47925.0 | 100.0 |

4.5.1.2 Status of the environment in the region: Given the availability of water from the Rihand reservoir and the abundance of coal reserves, large open-pit coal mines and super-thermal power generation stations have been established in the region. This has resulted in rapid industrial development of the area. All the natural resources such as air quality, water quality (surface and groundwater), forests and natural vegetation, and agricultural land are being affected by the developmental activities. The key issues are:

(1) Air pollution mainly in the form of dust. This is primarily due to soil erosion followed by coal mining, loading and transportation activities. Combustion of large amounts of coal in thermal power plants produces sulphur dioxide ($SO_2$), oxides of nitrogen, fly ash etc.

(2) Water related problems including contamination of Rihand reservoir from fly ash, huge quantities of sediments from mining area and a high concentration of iron and chloride in some of the ground water.

(3) Loss of forest areas and agricultural lands due to acquisition of land for industrial and residential purposes.

(4) Displacement of local population.

(5) High growth rate of population largely due to migration from within and outside the region.

## 4.5.2 Development scenarios

4.5.2.1 Power generation: Under an environmental study conducted by the National Thermal Power Corporation, Government of India, two main scenarios of development (most likely and tentative) have been contemplated for power generation in the region. These are given in Table 4.17.

**Table 4.17.** Power generating capacity and coal requirement

| Item | Power Capacity (MW) | Coal Requirement (MW) |
|---|---|---|
| Existing | 6760 | 21.97 |
| Most likely scenario | 10510 | 35.35 |
| Tentative/Ultimate capacity | 18510 | 62.27 |

**Source:** Environmental Study of the Singrauli area, Synthesis Report, NTPC (March 1991)

Air pollution: The annual emission for the three scenarios are given in Table 4.18.

**Table 4.18.** Annual Emissions of Pollutants

(Thousand Tonnes)

| Pollutant | Existing | Most likely scenario | Tentative/Ultimate |
|---|---|---|---|
| $SO_2$ | 209 | 336 | 592 |
| CO | 6 | 9 | 16 |
| $NO_x$ | 219 | 352 | 621 |
| SPM | 6152 | 9898 | 17436 |
| HC | 3 | 5 | 9 |

Because of the higher ash content in Singrauli coal, large quantities of fly ash are produced. ESPs can reduce flyash emissions substantially. Accounting for bottom ash removed from boilers and fly ash collected from ESPs, approximately 6 MT have to be disposed every year. This quantity increases to about 11 MT in the most likely scenario and to 19.5 MT under the tentative/ultimate scenario. The estimated land area required for the ash ponds is given in Table 4.19. .lh8

**Table 4.19.** Estimated land area required for ashponds in the Singrauli region

| | Existing | Most likely | Tentative/Ultimate |
|---|---|---|---|
| Ash produced (MT) | 6.05 | 10.9 | 19.5 |
| Ash pond area (ha) | 836.5 | 1586.5 | 3186.5 |

**Source:** Environmental study of Singrauli area, Synthesis Report NTPC, Govt. of India (March, 1991)

**Coal mining**

Production: For operational purposes, the working section of Singrauli coalfield has been divided into 12 mining blocks. Of these, 9 are working mines and 3 are under preparation. In 1990-91, the production was about 25 MT. The tentative/ultimate capacity is assessed at 65 MT and the most likely capacity at about 52 MT per annum.

Land degradation: The total land required for mining operations is about 19,000 ha for all projects of which

nearly 9500 ha (50%) is under forests. Out of this, 6000 ha are under coal mining and related activities.

Compensatory afforestation: Following the introduction of the Forest Conservation Act, 1980, a compensatory afforestation scheme is to be prepared by the coal company with the help of the forest department and the State Government. These schemes envisage afforestation of equivalent area of revenue land or non-forest land or twice the area in degraded land provided by the State Government.

Dust: Dust is a severe problem for the Singrauli area. Studies conducted have indicated that the major source of dust is soil erosion followed by the coal mining, loading and transportation activities. The range of dust level is given in Table 4.20.

**Table 4.20.** Range of dust levels

| Zone | SPM ($ug/m^3$) | Total dust $ug/m^3$ | Sedimentable particles ($g/m^2$) |
|---|---|---|---|
| Vicinity of coal mines | 200-700 | 500-1200 | 20 to 150 |
| Vicinity of cement plant | 250-400 | 800-2000 | 15 to 70 |
| Industrial area with road traffic | 100-300 | 300-1100 | 5 to 30 |

Source Environmental Study of Singrauli Area, Synthesis Report, NTPC, Govt of India (March 1991)

Agricultural land: The acceleration of industrial activities in the region has increased the competition for land for industrial vis-a-vis agricultural use, particularly in the core area. This has resulted in decrease of agricultural land, especially in the Waidhan plain, where the most fertile land is located. The industrial activity has also resulted in displacement of local people.

Socio economic factors: Between 1971 and 1981, the population in the region registered an average annual compound growth rate of 5.59 per cent. The growth rate in the core area around the reservoir has been very high. This is mainly due to migration both from within and outside the region, largely due to increased industrial activity. Details are given in Table 4.21 . Currently, one-third of the population is made up of migrants.

**Table 4.21.** Growth of population in the Singrauli Region, 1971-2001

| | 1971 | 1981 | 1991* | 2001* | 1991-2001 % change | Annual compound |
|---|---|---|---|---|---|---|
| Core Area | 74,641 | 141,929 | 450,606 | 1,046,217 | 132 | 12 25 |
| Non-core area | 159,677 | 205,651 | 245,723 | 348,739 | 41 | 1 80 |
| Singrauli region | 234,318 | 347,580 | 696,329 | 1,394,916 | 100 | 7 20 |

*: estimated

## 4.5.2 Delhi

Until recently, energy planning in India was done with little concern for environmental effects of energy production, conversion, transportation and utilization. However, the implications of one or more of these steps in the energy chain may be particularly significant in areas of concentrated population such as large metropolitan cities. The situation of Delhi, with a present population of over 8 million, is typical of these concerns.

Over the past two decades, Delhi has witnessed rapid industrialization and the consequent influx of population from neighbouring states. Undoubtedly, these activities are signs of economic development of the region but there are adverse environment related problems associated with it.

Among the environmental effects that may be considered is the impact of air pollution on human health. Delhi records 12 times the national average for respiratory ailments mainly due to unchecked pollution (National Capital Region Planning Board, 1987). The ambient air quality data show that the annual and 24-hourly mean values for $SO_2$ and $NO_x$ did not exceed the stipulated standards during 1989 whereas the annual mean values for TSP exceeded 200 ug $m^{-3}$ at all the six monitoring stations. The annual minimum, mean and maximum values observed at Shahzada Bagh (where the levels are maximum) are 3, 9.9, 46.7 for $SO_2$; 4.5, 21.2, 78.2 for $NO_2$; 165, 510, 1932 for TSP respectively.

The three major polluting sectors are power, transport and industry. At present, there are four thermal power stations in Delhi having a total generating capacity of 1320 MW, of

which 180 MW is run on gas. These thermal power stations consume about 3.7 MT of coal per year and 50,000 tonnes of furnace oil. Moreover, an additional capacity of 210 MW is proposed for future.

With increasing population, the transportation needs are growing rapidly. Vehicle population in Delhi has reached 1.7 million and every year 0.17 million vehicles (500 vehicles a day) are being added to it. The growth of motor vehicles was around 20% per annum between 1970-71 and 1986-87. Of all the vehicles, two-wheelers have registered a maximum growth of 12.7% per annum. Overall growth of personal vehicles is around 10.5% as compared to public transport vehicles such as taxis and autorickshaws (three-wheelers), which have registered a growth rate of 3.6% and 6.8% respectively. This has resulted in a major change in the modal mix for Delhi. There has been a marked shift away from the public modes of transport to the private modes The trend has led to congestion, thereby reducing the speed of vehiclular movement and their fuel efficiencies. This has resulted in high pollution levels, and a steady deterioration in the quality of air. As no major policy intervention to reduce the growth has been initiated, the transport situation of Delhi might deteriorate further in the future. The two major fuels used for the propulsion of vehicles are motor spirit and high speed diesel oil. The consumption of these fuels in the city during 1988-89 was 572,000 tonnes (High Speed Diesel) and 293,000 tonnes (Motor Spirit).

Exhausts from transport vehicles are characterized by large amounts of CO, $NO_x$, TSP as well as relatively smaller amounts of $SO_2$. In the absence of any control of emissions from automobile sources, exhaust gases contribute significantly to urban air pollution. The atmospheric pollution problem is further aggravated because the atmospheric conditions do not favour the dilution of pollutants most of the year around

Similar impacts can be attributed to the utilization of petroleum products and traditional fuels in the small scale manufacturing industries clustered in Okhla, Naraina Vihar and other industrial estates.

To quantitatively assess the severity of the problem, annual emissions of four pollutants---$SO_2$, CO, $NO_x$ and TSP---are estimated for the period 1989-90 and are presented in Table 4.22.

It can be seen that total emission of CO was the highest (1,921,000 tonnes), followed by TSP (154,040 tonnes), $NO_x$ (132,670 tonnes) and $SO_2$ (50,400 tonnes) during 1989/90.

CO emissions are maximum from transport sector (87%), followed by industry (12.5%). Particulate emissions are maximum from industries (69%), followed by power (28%) and transport (3%). Maximum $NO_x$ emission is from the transport sector (65%), followed by power (29%) and industry (6%). Finally, the major source of $SO_2$ emissions is the power sector which contributes nearly 74% of the total, followed by industry (13%) and transport (12%). It can therefore be inferred that transport sector is largely responsible for CO and $NO_x$ emissions, whereas industry is mainly responsible for TSP and $SO_2$ emissions.

The projected emissions levels in the target year as given in Table 4.22 shows that CO and $NO_x$ levels are likely to grow rapidly vis-a-vis other pollutants. This is mainly due to the rapid expansion of the transport sector. Thus, the strategy to reduce emission levels in Delhi, should target the transport sector as a priority area. The other area which needs attention is the control of TSP (which is at present far exceeding the standard). Since it is mandatory to install ESPs for power plants, it is the industrial sector where control technologies need to be focused.

**Table 4.22.** Emission of Pollutants by Energy Consumption in Delhi : 1989-2010 (thousand tonnes)

| Sectors | $SO_2$ | | CO | | $NO_x$ | | TSP | |
|---|---|---|---|---|---|---|---|---|
| | 1989 | 2010 | 1989 | 2010 | 1989 | 2010 | 1989 | 2010 |
| Power | 37.34 | 46.13 | 0.97 | 1.2 | 38.25 | 39.5 | 43 | 52 |
| Transport | 6.39 | 23.60 | 167.02 | 837 | 88.04 | 150 | 5 | 15 |
| Industry | 6.67 | 6.67 | 24.18 | 24.18 | 6.38 | 6.63 | 107 | 106 |
| Total | 50.40 | 76.40 | 192.17 | 862.38 | 132.67 | 196.13 | 154 | 173 |

CHAPTER
5

---

## Measures to combat environmental impact

---

### 5.1 Introduction

A move towards rational and environmentally-responsible energy use patterns and practices would require the creation of appropriate incentives consisting of appropriate governmental policy interventions. While these interventions would rely on policy instruments such as fiscal, tariff, and administered price regimes, there may be a need to retain regulatory instruments which are more direct*.

The choice of policies/instruments has to be viewed in the context of the existing political scenario, legal structure, and administrative capacity besides, theoretical and empirical considerations of their likely effects.

The Indian economy is characterized by private, public (and to some extent co-operative) forms of ownership in the industrial and service sectors, and largely private ownership by small landholders in agriculture. The public sector dominates several industries in the share in total output and capital investment, e.g. commercial energy, steel, petrochemicals, non-ferrous metals, etc. as well as several service sectors, e.g. railways, air transport, banking, and insurance. The extent of such dominance is often such that public sector firms have considerable influence over the price of their outputs. In addition, public sector firms do

---

* This is because some of the relevant markets may be too thin, or otherwise characterized by pervasive failures. A fundamental distinction is made in the environmental economics literature between market-based (or "incentive based") and fiat (or "command and control") instruments for pollution regulation. This latter category of policy instruments may include quantity restrictions (including those on emissions), and mandated technologies or technical performance standards (for example energy conversion or end-use efficiencies), besides others. The received wisdom of neo-classical economics is that, in general, market-based instruments ensure cost minimization for any given environmental standard whereas fiat instruments cannot.

not (in all likelihood), adhere to the neo-classical paradigm of profit maximization (or even cost minimization for a given level of output), and accordingly, their input and output choices are often found to be insensitive to market (price) incentives and remain largely unaffected by direct regulatory measures. Moving towards greater privatisation of industry thus seems not only desirable but is probably the only feasible solution to increasing total factor productivity, including energy.

However, the private sector as a whole is characterized by an appreciable proportion of enterprises belonging to the "unorganized" sector, which are neither incorporated, nor maintain detailed accounts, nor are subject to professional audit. One result of this is widespread non-compliance with direct and indirect taxation regimes, making these instruments only partly effective. As bringing this sector under effective control of the administrative machinery is a near impossible task given its size and dispersion, market based instruments appear to be the desirable means of promoting energy efficiency and environmental consciousness.

With the principal public policy focus on increasing GDP growth rates and per capita incomes, and the abysmally low per capita energy consumption levels, actual reductions in energy use cannot be contemplated - either in aggregate or in per capita terms. However, the energy intensity of the economy can be improved while promoting the twin objectives of growth and enhancing environmental quality by adopting the following broad measures :

(1) Strengthening the environmental policy and reformulating related policies to ensure a sustainable development path while keeping in mind national objectives of growth.

(2) Encouraging/promoting more efficient use of energy.

(3) Promoting the development and use of more environmentally friendly energy forms.

## 5.2 Strengthening and reformulation of policies

### 5.2.1 Environmental policy

The environmental policy in the country today is by and large restricted to requiring the industry to submit an assessments of environmental impact of various projects before they are undertaken. While emission standards have also been specified for particular pollutants, there is insufficient monitoring and implementation of these standards. The environmental policy needs to be strengthened through

stringent legislation to limit emissions from various activities, followed by proper monitoring and control. The imposition of taxes (penalties) on emissions of pollutants (if exceeding the stipulated limits) would convey to consumers the environmental costs of consuming particular types of products, as well as encourage a shift towards more environmentally benign energy forms and final products.

### 5.2.2 Energy policy

The first and foremost requirement is for the Government of India to recognize that the various forms of energy need to be viewed holistically. Integrated energy planning is essential for ensuring an optimal allocation of resources. The fragmented nature of energy planning today brings narrow sectoral interests to the fore and does not take into account the inter-fuel substitution possibilities that exist in the economy, resulting in a sub-optimal production mix. As a result, each energy department concentrates its efforts towards increasing supply irrespective of availability of alternative energy forms and fuel substitution possibilities. Planning for energy demand shifts and management is more or less non-existent. To the contrary, any private efforts to improve efficiency through the use of co-generating systems are dampened by the requirement of obtaining permission from the respective state electricity boards.

### 5.2.3 Investment policy

Due to the fragmented nature of planning and lack of an overall perspective, investment decisions for the energy sector tend to be based on short-term targets and benefits. For instance, despite increasing transmission and distribution losses and poor performance of existing power plants, the focus of investments in this sector has been on increasing generating capacity. Similarly, despite the fact that natural gas is a convenient, efficient and environmentally benign fuel to use, 30-40% of the gas produced continues to be flared annually - a totally non-productive and polluting activity. In addition, the abundant renewable energy resources of the country have been given a very low priority with less than 1% of total energy outlay earmarked for this sector.

The procedural red tape in getting clearances for various investment projects results in delays and cost overruns - particularly in public sector projects such as those of energy. This necessitates the use of petroleum products as

swing fuels. Combined with operational inefficiencies of the public sector, this has resulted in increasing the incremental capital-output ratios in the energy sector. Furthermore, as these high costs are not reflected in the price structure, particularly of coal and electricity, the financial health of these organisations is poor.

5.2.4 Pricing policy

It is widely recognized that in many countries, inefficient energy use is a consequence of the failure of energy prices to reflect the full social costs. This may be on account of "irrational" administered pricing regimes (in the sense of prices being politically determined from considerations other than economic efficiency), or the failure of markets to reflect environmental externalities, or being non-competitive, or due to direct and indirect subsidies on energy use. Administered prices for commercial energy in India do not, in general, reflect the principle of marginal (or even average) cost pricing. Further, the relative prices often convey signals that run counter to desired directions of inter-fuel substitution.

A rational integrated energy pricing structure reflecting the full costs of environmental damage could achieve the objectives of promoting energy and environmental use efficiencies and fuel substitution in desired directions while keeping in mind the overall social objectives. In addition, the introduction of seasonal and time-of-use prices would encourage consumers to manage electricity demands better.

5.2.5 Fiscal policy

The category of fiscal incentives for greater energy efficiency may include indirect taxes on energy sources as well as taxing inefficient use of energy, such as private transportation, while subsidizing more efficient uses, such as mass transportation. Other fiscal strategies, for example indirect taxation of energy intensive sectors such as steel or aluminium manufacture, may have the effect of significantly reducing overall energy consumption in the economy, by promoting factor or material substitution. The structure of federal and state taxes/subsidies, which are governed by political motivations, distort the present structure substantially, which leads to heavy losses to the economy not only in energy use but also in terms of financial resources. Further, instruments such as carbon taxes and tradeable permits may also be operated by modification of the existing fiscal regimes.

5.2.6 Industrial policy

The Indian economy has largely been a controlled economy and most industrial expansion programmes have to be licensed by the Government of India. While a certain amount of decontrol has been introduced in the recent past, the industrial policy could still influence, to a large extent, the types of industries and technologies/ processes that are to be set up in the country. A first step in promoting efficient use of various resource inputs is to introduce fair competition. To ensure complete fairness, the cost of energy to industry should also be rationalised -- Indian industry pays a very high price for the energy it consumes as compared to those in other countries. In the formulation of the industrial policy, due regard should be given to the availability of energy and the costs of supplying these energy forms.

5.2.7 Transport policy

Transportation infrastructure planning should go hand in hand with regional development planning and urban development planning. Adequate, reliable and efficient mass transportation capacity should be ensured to discourage the use of private modes of transportation. Unfortunately, in the eighties, the GOI actually encouraged the use of private means of transport through the introduction of low-priced cars and large scale licensing of two-wheeler production capacity.

Inadequate investments in the railways have led to an increasing dependence on the more energy intensive forms of road transportation. Major R&D efforts are called for to improve efficiencies of different modes of transport and to switch to alternative energy forms such as CNG both in road as well as rail transport.

5.2.8 Trade policy

A major focus of trade policy should be to facilitate the creation of infrastructure and regional markets for energy resources such as hydroelectricity and natural gas which are available in abundance in some of the neighbouring countries. The constraints on such developments are well recognised and include the issues of security of pipelines or transmission lines from hostile environment, the question of energy and infrastructure pricing in monopoly-monopsony market structures, the denomination of an appropriate currency for transactions, devising adjudication mechanisms for disputes, and adopting convergent technical standards and practices.

5.2.9 Agricultural policy

As mentioned earlier, energy intensity of the agricultural sector is growing partly because of the need to increase productivity and partly due to the inefficient utilization of energy. While efficiency improvements can be affected through a proper pricing policy, agricultural policy can also play a significant role in ensuring, through the procurement price structure, a rational cropping pattern in various regions of the country which is suited to the available local resources.

Finally, there is an extensive system of land records, enforcement of land ownership and tenurial rights, and forestry records and management. The significance of the last aspect lies in that it may make feasible the adoption of regulatory regimes for $CO_2$ emissions, which treat forestry plantations as an abatement industry.

## 5.3 **Potential for more efficient use of energy and inter-fuel substitution**

Energy efficiency improvements can be classified as efficiency improvements in production, conversion, transportation/transmission and end-use efficiency improvements. From the environmental point of view, the following measures are significant: (i) increase in the conversion efficiencies of coal-based thermal power plants; (ii) washing of coal which has implications for both transportation and end-use energy demands; (iii) reduction of transmission and distribution losses for electricity; and (iv) efficiency improvements in each of the consuming sectors, viz. industry, transport, agriculture, domestic and the commercial sectors.

5.3.1 Efficiency improvements in thermal power generation

Thermal (coal-based) power plants in India are consuming a larger quantity of energy per kWh of power generated than the established norms for a number of reasons. These include (i) inferior quality of coal supplied to power plants which results in inefficient operation of boilers; (ii) inappropriate use of thermal power plants as peaking plants due to short-term investment priorities; (iii) a larger amount of oil being consumed per unit of power generated due to both the above factors. Overall thermal efficiency of power plants can be improved by a more optimal use of existing power generating capacity and by removing the imbalance that exists in the power utilities with regard to

peak and off-peak generating capacities. Technological changes/retrofitting of components in existing thermal power stations can also lead to increased energy efficiency.

5.3.2 Reduction in transmission and distribution (T&D) losses

T&D losses in the country have been increasing over time and it has been estimated that these losses can be brought down from the present level of approximately 23 per cent to at least 15 per cent.

5.3.3 Washing of non-coking coal

Indian coals on an average contain 35 per cent of ash. The washing of non-coking coals is desirable as (i) the consumer is provided with low ash non-coking coal leading to a reduction in emissions of pollutants at least in the industrial sector; (ii) the middlings that are produced in the washing process can be used by industry or power utilities leading to an overall improvement in energy utilisation efficiency; (iii) the washing of coal reduces energy consumption indirectly in the economy as a whole because a lower amount of ash is transported.

5.3.4 Efficiency improvements and fuel substitution in the demand sectors

5.3.4.1 Industrial sector: The industrial sector accounts for the major part of commercial energy consumption in the country. Surveys carried out by various organisations reveal that the conservation potential in the industrial sector (through good housekeeping measures in the short term and through process modification, modernisation, etc. in the long term) is close to 20 per cent. Industries could contribute to a lower electricity intensity in the economy through measures such as efficiency improvements of motors, refrigeration equipment and lighting systems; demand management to smoothen the load curve by rescheduling of operations and by ensuring a proper matching of various pieces of equipment used in the system as a whole. On the thermal energy side, industry could contribute by improving efficiencies of boilers and furnaces, better heat transfer, proper insulation, waste heat recovery and through co-generation to the extent possible. Boiler efficiency levels in the country vary from 45 to 80 per cent, revealing a significant scope for thermal energy conservation. The industrial sector also has a significant potential for reducing overall energy intensity through process and technological changes. For example, the use of naphtha as a feedstock in the fertilizer and petrochemical

sectors could be substituted by the use of natural gas. Similarly for some of the low process heat demands of industry, renewable solar thermal options can be considered.

5.3.4.2 Transport sector: Surface transport forms a major part of transportation in the Indian economy. Railways and roadways together account for close to 90 per cent of total transportation. Unfortunately, over the last few years, there has been an increasing trend towards meeting a major share of transportation energy requirements through road-based movements rather than the more economical and efficient railway system.

Strategies to reduce the increasing energy intensity of (surface) transportation in India could center on the following steps:

(1) A shift in both commuting and long distance passenger travel from personalized to mass transport.

(2) Within the mass passenger transport subsector, a shift from road to rail transport.

(3) Similarly, in the case of long distance freight movement, a shift from road to rail transport.

(4) Introduction of more energy efficient vehicles for passenger and freight movements.

(5) Electrification of railway routes to the extent that is economically desirable.

(6) Widening and improvements in the telecommunication network leading to reduced transportation energy demands.

It is generally believed that the increasing use of personalized modes for commuting is because of inadequate public investment in mass transport, i.e., buses and suburban/metro rail. Budgetary constraints lie at the root of inadequate investment in mass transport, including long distance rail. However, since personalized transport is more energy and capital intensive than mass transport, the problem is not one of inadequate capital investment in transportation as a whole.

Some policies which may motivate shifts to mass transport systems can be identified. These are:

(1) Institutional changes to facilitate the participation of private operators in mass transport.

(2) Ensuring that the private transportation markets are competitive. This would require complete deregulation of routes, fare structures, and vehicle design features (except for safety and pollution regulation), and a shift in public investment patterns from road transport fleets to long term fixed transport

infrastructure, i.e., the roads network.

(3) Since the sharing of railway infrastructure by numerous operators is still technically difficult, the railway network would need to remain wholly in the public sector in the foreseeable future. There would thus remain the need to locate public budgetary resources for increased investment in railways.

3.4.3 Household and commercial/service sectors: The main end-uses for which energy is required in these sectors include cooking, lighting and heating systems. In the household sector, most rural energy demands are met through the use of biomass fuels. Urban energy demands are catered to by petroleum products and electricity. It is highly unlikely that the dependence on biomass fuels in the rural sector will reduce significantly in the coming few decades. Therefore, more attention needs to be focused on developing appropriate technologies for more efficient utilisation of biomass resources. These measures can include improvement in utilisation efficiencies of devices such as cookstoves as well as improvements in the conversion efficiency of biomass through technologies such as biogas plant and gasifiers.

In the urban household sector conservation potential exists in both electrical and non-electrical energy uses. Non-electrical energy forms mainly comprise LPG and kerosene which have a small conservation potential. However, a significant potential exists in improving the efficiency of electrical devices such as lighting systems, refrigerators, air-conditioners and water heating systems.

In addition to a rational pricing structure, legislative measures may also have to be resorted to for ensuring minimum performance standards of these devices. The commercial sector has very similar energy needs as the residential sector and similar measures would be effective in promoting energy efficiency in this sector.

).3.4.4 Agricultural sector: The principal commercial energy inputs in agriculture are diesel and electricity. The dominant energy source is, however, electricity. Conventionally, this is explained by the fact that several public electric utilities charge a flat tariff based on the horsepower of agricultural pump-sets, and not on metered consumption. Further, the electricity tariff rates in agriculture are extremely low, and yield no more than a few percent of the LRMC of delivered power as revenue to the utilities. This fact is also believed to have contributed appreciably to increased energy intensity of agriculture because of wasteful electricity use.

The key to improving energy efficiency in agriculture is the adoption of an electricity tariff structure which would create incentives for less wasteful use of electricity, and rectification of technical deficiencies in existing pumping systems.

In addition, irrigation practices in the country are not geared towards an efficient utilisation of resources, either energy or water. The general practice is to flood the area to be irrigated. Introduction of sprinkler and drip irrigation systems could contribute significantly to an efficient utilisation of resources.

Efficiency improvements in diesel consumption could also be effected through a proper land utilisation policy. The fragmented nature of land-holdings today is not very conducive to efficient operation of tractors.

## 5.4 Potential for the increased use of renewable energy

While Renewable Energy Technologies (RETs) could come to play a significant role in reducing adverse environmental impacts, it is expected that only small and mini hydel plants and wind electric generation in the grid connected mode are likely to play a significant role by 2010. Photovoltaic systems have so far been limited to small applications, as the technology is still not economical for large scale power generation in grid connected or autonomous modes. Its use in future will be limited to autonomous, small and remote applications and the overall impact on the power sector will be negligible.

### 5.4.1 Wind electric generation in grid connected mode

Based on the findings of a study to assess the cost and reliability of wind electric generators at different levels of penetration of wind farms in the power system of the Tamil Nadu Electricity Board (TNEB), it can be said that the technically realisable potential for windfarms in India can be computed on the basis a of 35% level of penetration. This potential is very large and in spite of special efforts, the actual installations are likely to be much lower than these figures.

Constraints: The major constraints to installing such wind farms are related to the availability of funds, logistics and the world wind turbine turnover capacity. These are discussed as follows:

Funds: The capital cost of windfarms at present is about US$ 1500/kW, net of customs duty of about 40%. The cost of

indigenously produced wind electric generators is expected to be in the range of US$1667/kW. It is estimated that the budgetary requirements to meet the windfarms potential at 2010 is US$ 73 billion for the 5% GDP growth scenario and US$ 78 billion for the 6% growth in GDP.

Logistics: Identification of sites, land availability, modifications in existing grid and actual execution of the projects are the major factors to be considered. Earlier studies have shown that the land and wind resource availability are not the major constraints. However, lack of experienced and adequate manpower for preparation of specific project details would be a bottleneck.

Annual production capacity: Wind turbines are not domestically produced at present. Also, the world production capacity would have to cater to the increasing demand from Europe, USA and other parts of the world. In Europe itself, a potential of 100,000 MW of windfarms has been identified to be met over the next 40 years or so. The highest turnover from the world wind turbine industry in the last decade has been of about 500 MW. The production capacity is likely to increase with an increase in demand but this increase again is limited and time dependent.

5.4.2 Strategies for increased grid connected windfarms

It has been established that windfarms connected to the grid not only reduce the fuel consumption but also offer some firm power at the time of peak demand. Grid connected windfarms can be promoted by a two-pronged strategy: (i) modifying the conventional power system to accept more energy from windfarms; and (ii) promoting indigenous R&D and production of wind turbines.

In a study conducted on Tamilnadu power system, it was observed that increased capacity of pumped hydro units (acting as energy storage facilities) in the system can substantially increase the utilisation of energy from windfarms. The pumped hydro option makes it possible to absorb the load demand and smoothen wind fluctuations effectively. As the generating capacity in India is still growing, it is easier to plan the system expansion keeping in view the possibility of a large penetration of windfarms.

The private sector is already being encouraged to participate in windfarming by allowing 100% depreciation in the first year and wheeling of energy generated to the industry's plants. In Tamil Nadu a wind energy cell has been established which facilitates the project implementation for the industries. This, however, has not been done in Gujarat

and Maharashtra. Large installations of windfarms will require an approach similar to that followed by the TNEB.

### 5.4.3 Strategies for increased small hydro utilisation

Small hydro is perceived to be both unreliable and a high cost option among those responsible for decision making in the Indian energy sector. These two factors have led to doubts about the possible role of small hydro in the Indian energy system. However, the reliability of the small hydro system can be substantially increased through innovative and interlinked design of small hydro facilities. A recent World Bank survey of the designs of small hydro facilities reveals the possibility of bringing down the unit cost of small hydro plants to one-third of the current costs (which are in the range of Rs 25,000-30,000/kW) by a combination of design modification and standardization of equipment.

The initial batch of small hydro schemes in India were conceived, designed and executed as scaled down versions of large conventional hydro installations. As a result of this there are numerous redundancies in the designs for the key features such as the layouts for the civil works, the facilities incorporated into the powerhouse structure, the selection of turbine-generator equipment, and the specification of the electrical switching and protection system.

There are other measures which can result in further improvement but will require a longer timeframe to implement. The design of small-hydel projects on a river basin basis on the principle of cascade development, like the Chinese small-hydel programme, can be a major factor in increasing the potential and the success of the Indian programme. In planning small hydel projects for small river basins, the emphasis should be placed on evolving designs to take advantage of the topography and to arrange the hydropower structure such that the headwork (or the intake) of one station follows closely the tailrace (open canal for tail water) of the other. The upstream regulating reservoirs can then be designed so that the cascade process raises the dependable output of the whole basin system. Such cascade systems, which can be as much as 10-20 MW, can then be integrated to form a local grid. These local grids, in turn, may be connected to a regional grid. Small hydro developed in this fashion can result in rural electrification that is fundamentally different from that of today: electrification will not simply be the extension of the

large grid systems, but rather through the development and gradual interlinking of many small, but growing, local grids. This can have a profound impact on the way in which rural electrification is visualised and implemented.

The standardization of the hydroelectrical equipment (water turbine-generator combinations) through establishing technical specification and the consequent improvement in the quality of manufacture and reduction in unit costs by enabling specialized production in batches is another measure which can go a long way in making implementation of small-hydel projects reliable and quicker. This is likely to have another very favourable spin-off. China is a good example. Measures to standardize designs of the equipment for small-hydel stations in China started in 1978. The result of this ongoing and evolving exercise is the stipulations for 4 types of turbines, 8 runner series and 32 product varieties. About 85% of all the components now have standardised designs making the production process economical and the components reliable. The standardization process has resulted in products in the capacity range of 500-10,000 kW suitable for water heads of 3-450 m. By 1989, the estimated number of hydroelectrical manufacturers had touched 100 and the annual production capacity exceeded 1000 MW.

CHAPTER
6

## Alternative energy development strategies

### 6.1 Introduction

As evident from chapters 3 & 4, the business-as-usual strategy of development will result in significant energy shortages -- both for the 5% and 6% growth scenarios. These shortages and adverse environmental impacts can be mitigated by adopting the following two strategies:

(1) A concerted effort towards improving the efficiency of energy production, conversion and use; management of energy demand and encouraging technology/process changes;

(2) Moving towards more environmentally benign energy forms which may be more efficient to use (for instance, natural gas) or renewable in nature (such as wind energy).

Both these strategies have been designed to comprise mutually exclusive measures so that a combination strategy comprising of both energy conservation and alternative energy measures can be readily evaluated.

### 6.2 Strategy I : Energy efficiency improvements and conservation

The need for energy conservation from the point of view of environment has been highlighted in chapter 5. Energy conservation is mandatory not only for such reasons, but also because of its direct implications on the availability of energy to a larger section of the population and foreign exchange outflows. This section analyses specific energy conservation measures that can be implemented, both on the demand and supply fronts, in the next 20 years and estimates the investment requirements of doing so.

6.2.1 Measures on the demand side

6.2.1.1 Industrial sector: Energy conservation measures have been analysed for three types of industries. The assumptions made for this sector based on discussions with industry experts

are outlined below.

(a) Steel: Indian integrated steel plants tend to consume nearly 60% more energy than their counterparts abroad.

A major part of energy consumption in the steel sector is at the blast furnace/crude steel making stage. Typical energy conservation/productivity improvements result from:

improved control over-burden preparation
improved process control
injection of pulverised fuel to substitute coke
better energy recovery from top gas and from using the high top pressures employed in modern furnaces to drive the turbine
longer campaign life through improved refractory and cooling systems
alternative form of heat energy etc.

**Table 6.1.** Comparison of energy efficiency of Indian plants vis-a-vis other countries

| | Energy consumption in Gcal per tonne of crude steel | Coke rate |
|---|---|---|
| Italy | 4.2 | 463 |
| Japan | 4.5 | 484 |
| U.K. | 5.6 | 557 |
| Brazil | 5.7 | 480 |
| India | 9.8-13.7 | 735-1188 |

**Source:** GOI (1989a).

A study carried out by the Bureau of Industrial Costs and Prices on particular steel plants points out the possibility of reducing energy consumption in these plants from the present level of 7.2 to 8 Gcal/metric tonne of crude steel to a level of 5.5 Gcal/metric tonne. Extrapolating this for other steel plants it is estimated that the investments that would be required for achieving this level of efficiency improvements would be in the range of $10994.8 million for integrated steel plants. Since capacity additions in this sector remains the same for 5 and 6 per cent rate of growth of GDP scenarios, investment requirements for energy conservation remains the same.

(b) Cement: In the case of cement industry it has been assumed that the remaining wet process capacity in cement

production under BAU would be completely replaced by the dry process technology. An additional 10 per cent reduction on the specific consumption norms for the dry process by close circuting of the cement mill by installation of high efficiency separator, X-Ray analyser for speedy process control and replacement of low efficiency fans by high efficiency ones have been considered. The investment requirements for doing the above have have been estimated at $767 million.

(c) Chemicals and petro-chemicals: A case study of the National Organic Chemical Industry Ltd. (NOCIL) which succeeded in achieving a specific fuel consumption level of 0.947 tonne of naphtha equivalent fuel per tonne of output against the prevailing level of 1.257 tonne per tonne of output through specific energy conservation measures has been used for studying the implications of energy conservation in this sector. It has been estimated that a minimum reduction of 20 per cent is absolutely essential for firms to be financially viable. To achieve an energy savings of 20 per cent in the organic chemicals sector an investment of $483 million has been estimated. The major non-organic chemicals wherein energy conservation could be effective are soda ash and caustic soda. While there has been no major technological breakthrough in the production of soda ash, industry experts are of the opinion that the requirement from the membrane cell technology for producing caustic soda would be as low as 40 per cent of the present level. To achieve an energy savings of 30% in this sector and investment requirement of $1318 million has been estimated.

6.2.1.2 <u>Transport sector</u>: The following measures that are likely to result in reduced energy consumption levels in transportation have been taken into account:

(1) A shift from road transportation to rail transportation for both passenger and freight traffic. The National Transport Policy Committee of the Government of India had recommended a rail-road mix of 40:60 in passenger transportation and 72:28 for freight transportation. It has been assumed that this mix would be achieved by the year 2009-10 from the present levels of 21:79 for passenger transportation and 51:49 for freight transportation.

(2) The road user cost study again by the Government of India has estimated 10 per cent fuel efficiency improvements due to various measures adopted for improving road conditions. The range of road

improvement measures include low grade section to be updated and widened, single lane road to be widened and strengthened, strengthening two lane pavement etc. This has been adopted here. Road improvements also bring other benefits like improvement in tyre life, engine life, etc., which is not accounted for in the present study.

(3) Introduction of more efficient buses (termed as urban bus) for intra-city passenger transportation could lead to an efficiency improvement of 10 per cent. Urban bus has a design capacity of 60 and crush loading of 90. It has low floor height with a new and more efficient engine. It is fuel efficient and at lower speeds emits less pollutants. Urban bus is faster than the standard bus under urban conditions due to better acceleration. Its weight is less because of the use of lighter material. The investments that would be required for effecting the above savings are to the tune of $69799 million.

(4) At present, the only urban rail transport system in India are in Bombay and Calcutta. Urban rail transport systems lead to a reduction in energy consumption and emission reduction. A detailed feasibility report prepared by Rail India Technical and Economic Services (RITES) for the city of Delhi from the basis for analysis. It is estimated that the metro system on an average would cost US$ 1.39 billion and provide a capacity of 20 BPKM annually. In the present study, urban rail transport (metro) in Madras and Delhi and seven cities with population between 2 and 8 million has been recommended. Feasibility of a metro in the North-East region is not considered because of low density corridors. The capital (including the interest) required is spread out at the rate of 40%, 30%, 20% and 10% for the periods 1994/95, 1999/2000, 2004/05 and 2009/10 respectively.

6.2.1.3 Domestic sector: Efficiency improvements in this sector can take place in the following activities : cooking, lighting, water heating and other electrical appliances.

(a) Cooking: It has been assumed that there esists potential for a 5% improvement in the present average efficiency of LPG stoves the turn of the century and by 10 per cent by the year 2009-10. In case of kerosene stoves and cookstoves using soft coke an efficiency improvement of 10 per cent has been considered for each of the years under

study.

(b) Lighting: For lighting purposes, the option of replacing incandescent bulbs with fluorescent tubes has been considered. We analyse the case where all the additional incandescent bulb connections in the households as per the BAU-scenario will get replaced by half as many fluorescent connections. This is because the lumen output of one 40 watt 4 feet long fluorescent tube is approximately the same as that of 2 incandescent bulbs of 100 watts each. If, however, a 40 watt fluorescent tube was used to replace two 60 watts incandescent bulbs, the lumen output would actually increase [TERI (1990)].

(c) Other electrical appliances: The Tata Energy Research Institute had recently carried out a survey of energy efficiency of domestic appliances in use today [TERI (1991)]. On the basis of the results of this study, in case of air-conditioners, a 20 per cent efficiency improvement over the present levels has been assumed through proper maintenance of air-conditioning systems alone. In the case of refrigerators, an efficiency improvement of 30 per cent resulting from minor maintenance and regular defrosting is assumed by the year 1999-2000. From 1999-2000 to 2009-10 it has been assumed that 25 per cent of the old stock will get replaced by more energy efficient refrigerators. For the balance 75 per cent regular maintenance will result in a 30 per cent energy conservation. In case of ceiling fans, a small efficiency improvement of 5 per cent in energy consumption is assumed to be achievable by minor maintenance measures such as regular greasing etc. The investments that would be required for implementing the above mentioned measures are estimated in the range of $3699 million. The aggregate energy requirements for all the measures listed above [(a) (b) & (c)] amount to about $3700 million.

6.2.1.4 Agriculture sector: One of the major end-uses for which energy is consumed in the agricultural sector is irrigation. Table 6.2 summarizes the expected savings from the various retrofit measures that have been considered and the distribution of pumpsets on which each of these measures would be applied. The investments that would be required for implementing these retrofit measures are of the order of $578.7 million.

Further, an option of more efficient irrigation practice has also been considered. Thus, the option of using drip irrigation for crops such as sugarcane, cotton and oilseeds and sprinkler irrigation for maize and gram has been

considered with application efficiency of 95 per cent and 85 per cent respectively against present application efficiencies of less than 50 per cent. Investments that would be required for installing these irrigation systems are approximately $11309 million.

**Table 6.2.** Expected savings from different retrofit procedures[a]

| Retrofit measures | per cent of pumpsets | Expected savings |
|---|---|---|
| Involving subsystem components | | |
| 1. Replacement of foot valve and suction pipeline ($R_1$) | 30 | 8-12 |
| 2. Replacement of foot valve, suction, and delivery pipeline ($R_2$) | 40 | 10-20 |
| Involving subsystems | | |
| 3. $R_2$ + replacement of pump ($R_3$) | 10 | 20-40 |
| Involving entire system | | |
| 4. $R_3$ + change of motor (i.e.complete replacement) ($R_4$) | 20 | 30-50 |

[a] Abridged from Patel 1988.

### 6.2.2 Measures on the supply side

The major improvements considered in the performance of the energy supply industries are:

(i) a reduction in T & D losses, from 23% in the BAU strategy, to 18% in the conservation strategy. Of this reduction of 5%, about two-thirds may be considered to be in non-technical losses --- which implies that certain institutional constraints are partly removed;
(ii) non-coking coal washeries, for reducing ash content of steam grade coal used for thermal power generation, are established.

No significant improvements in the production efficiencies of coal and oil subsectors are assumed.

T & D losses are assumed to reduce from the present level of 23%, to 22.5% in 1999/2000, and further on to 20.5% by 2004/05 and 18% by 2009/10. Further, it is assumed that washing of non-coking coals reduces their ash content by about 7%. With this, the performance of the TPS will enhance, with an improvement in the plant heat rate from 2336 kCal/kWh to 2304 kCal/kWh, a reduction in auxiliary

consumption levels from 10% of gross generation to 9.58%, a reduction in coal utilization from 0.65 kg/kWh of gross generation to 0.44 kg/kWh (even if washery rejects are 20% of the coal feed, the input coal requirements are 0.55 kg/kWh), and a reduction in the oil use from 15ml/kWh to 10 ml/kwh. These performance indicators are derived from relationships presented in Appendix 6.1. The results are given in section 6.4.

## 6.3 Strategy II: Alternative energy options for meeting energy demands

In addition to efficiency improvements and demand management, there exists potential to develop alternative energy forms and substitutes towards the use of more environmentally benign energy sources. This strategy looks at the impact of doing so.

### 6.3.1 Demand side

Alternative energy options that have been on the demand side include the use of solar cookers, biogas plants and compressed natural gas as a transportation fuel.

On the basis of a recent analysis carried out by the Tata Energy Research Institute, it was found that the solar cooker is an economically attractive option only in small and medium sized towns and cities. Taking the present proportion of urban population for these cities (40 per cent) and assuming a penetration ratio of 20 per cent, savings in LPG consumption have been worked out. The same analysis indicated that solar cookers would be able to replace 20 per cent of LPG for cooking energy demands.

In considering the option of compressed natural gas as a transportation fuel, the transportation requirement of only those cities that are situated close to existing gas pipeline network were taken into account. The number of vehicles that could be converted to using compressed natural gas were obtained from Srinivas (1991). Test results have shown the efficiency of buses and trucks based on compressed natural gas to be in the range of 7.42 km/m$^3$ and of cars at 10.27 km/m$^3$. Investments that would be required for the utilization of CNG to this extent are in the range of 1.1 million of rupees.

The costs that have been taken into account include the costs of refueling station, distribution pipelines and operating costs. Costs of trunk pipelines have not been considered. This option is assumed to remain the same under both the scenarios.

In the case of biogas plants, it was assumed that the cumulative number of biogas plants will go up to 5.53 million of 2 $m^3$ capacity would be installed by the year 2010 under this scenario. Correspondingly, the number of cook stoves using biogas would also increase. This would have a dual impact on firewood consumption - first, through substitution of firewood by biogas and the second, through the higher efficiency of biogas stoves. Total investment that are required for this option are approximately $1163 million.

### 6.3.2 Supply side

The major changes on the supply side are the augmentation of power generating capacity through RETs, mainly windfarms and small hydro capacity. In view of the constraints mentioned in Chapter 5, a realisable target of 3000 MW of windfarms and 1500 MW of small hydel capacity can be added till 2010. Based on design considerations keeping strategy evaluation in view (section 6.1), the regional distribution of the generating capacities considered are given in Table 6.3.

**Table 6.3.** Power Generating Capacity additions from RETs in the 5% GDP growth case (MW) - Strategy II

| | April 1990 to March 1995 | April 1995 to March 2000 | April 2000 to March 2005 | April 2005 to March 2010 |
|---|---|---|---|---|
| Northern Region | | | | |
| - Windfarms | 0 | 0 | 0 | 0 |
| - SHP | 31 | 93 | 155 | 217 |
| Western Region | | | | |
| - Windfarms | 33 75 | 56 25 | 90 | 112 5 |
| - SHP | 15 | 45 | 75 | 105 |
| Southern Region | | | | |
| - Windfarms | 33 75 | 56 25 | 90 | 112 5 |
| - SHP | 35 | 105 | 175 | 245 |
| Eastern Region | | | | |
| - Windfarms | 7 5 | 125 | 200 | 250 |
| - SHP | 10 | 30 | 50 | 70 |
| North-eastern Region | | | | |
| - Windfarms | 0 | 0 | 0 | 0 |
| - SHP | 9 | 27 | 45 | 63 |
| All India | | | | |
| - Windfarms | 75 | 125 | 200 | 250 |
| - SHP | 100 | 300 | 500 | 700 |

These capacity additions are assumed for both the low and high GDP growth cases. In order to assess the acceptable levels of penetration (% of the peak generating capacity) of wind electric generators in the regional power systems in India, the working of one utility was studied for cost and reliability. The power system operated by Tamil Nadu Electricity Board (TNEB) was simulated with different levels of penetration of windfarms. The major findings of this exercise are:

(i) energy rejection increases significantly beyond the 35% penetration level;

(ii) system reliability is not adversely affected by windfarm penetrations of up to 35%;

(iii)fuel and running cost savings are not significant beyond a penetration of 35%; and

(iv) the contribution of wind generation in meeting peak load demand is small but could increase to 10% of peak demand if a large number of sites are considered.

The operation and nature of the generation mix of other utilities in India is similar to TNEB. The findings of this exercise, therefore, are assumed to hold for other utilities as well. Although the technically realizable potential of windfarms in India can be computed on the basis of a 35% level of penetration, the actual installations will remain much lower despite special efforts.

On the basis of the sites identified so far, the potential for microhydel units is estimated at 5000 MW. The ultimate potential in both grid connected and decentralised modes however, is very large. At present, the capacity of small units is only 0.55 MW. Although there are eight manufacturers of small hydro turbines, their production capacity is small. Several canal drop schemes and other small/mini hydro plants have been cleared, but their execution is likely to be delayed owing to lack of funds, difficult logistics and lack of experience in this field. The critical constraint will be the production capacity of turbines in the range of 50 kW to 500 kW.

## 6.4 Demand/supply situation resulting from the above two strategies

### 6.4.1 Demand impacts

As can be seen from table 6.4 below significant reductions can be affected in energy demands through the measures suggested above. However, no clear pattern of savings emerges

in sum as what is presented below is the net savings across sectors. Electricity and coal demands do not undergo any change under Strategy II whereas firewood consumption remains the same in strategy I. Table 6.4(a) presents the percentage change in demand for these fuels whereas, Table 6.4(b) gives the percentage changes in oil and gas demand due to implementing both the strategies independently.

**Table 6.4(a).** Energy savings under the 5% growth scenario

| | Electricity | | Coal | | Firewood | |
|---|---|---|---|---|---|---|
| | BAU (GWh) | Strategy I % change | BAU (MT) | Strategy I % change | BAU (MT) | Strategy II % change |
| 1994-95 | | | | | | |
| North | 91431 | 18.61 | 59 85 | 4 25 | 24 60 | 5 10 |
| South | 72228 | 12 54 | 63 38 | 11 40 | 37 69 | 4 63 |
| West | 90863 | 12 00 | 103.19 | 9 73 | 50 83 | 4 52 |
| East | 46056 | 14 12 | 85 42 | 21 21 | 25 84 | 3 66 |
| N East | 3597 | 9 93 | 2 94 | 13 39 | 8 03 | 2 97 |
| All India | 304175 | 14 41 | 314 78 | 12 17 | 146 99 | 4 41 |
| 1999-00 | | | | | | |
| North | 112487 | 15 97 | 78 13 | 13 87 | 26 77 | 6 83 |
| South | 95233 | 11 72 | 84 09 | 19 09 | 39 43 | 6 30 |
| West | 116019 | 10 13 | 125 03 | 16 06 | 55 23 | 6 03 |
| East | 56358 | 12 21 | 100 29 | 24.07 | 28 72 | 4 79 |
| N East | 4563 | 2 17 | 2 86 | 4.96 | 8 87 | 3 92 |
| All India | 384661 | 12 44 | 390 40 | 18 25 | 159 02 | 5 89 |
| 2004-05 | | | | | | |
| North | 143054 | 14 57 | 103 99 | 23 86 | 28 95 | 8 63 |
| South | 126796 | 11 21 | 108 31 | 14 65 | 41 13 | 8 06 |
| West | 153349 | 9.35 | 154 01 | 11 84 | 59 34 | 7 63 |
| East | 71760 | 9.21 | 121 06 | 20 59 | 31 95 | 5 86 |
| N East | 6153 | -2 07 | 4 64 | -1 85 | 9 86 | 4 80 |
| All India | 501113 | 11 15 | 492 01 | 17 02 | 171 24 | 7 41 |
| 2009-10 | | | | | | |
| North | 186100 | 11 66 | 143.90 | 25 49 | 31 29 | 10 45 |
| South | 174379 | 8 34 | 148 55 | 11 99 | 42 83 | 9 90 |
| West | 209247 | 5 31 | 195 68 | 9.29 | 63.70 | 9 24 |
| East | 94401 | 5 27 | 154 53 | 21 56 | 35 57 | 6 87 |
| N East | 8466 | -10.86 | 4 85 | -6.51 | 10 97 | 5 64 |
| All India | 672593 | 7.64 | 647 51 | 16 11 | 184 36 | 8.93 |

**Table 6.4(b).** Energy savings under the 5% growth scenario

| | Oil | | | Natural Gas | | |
|---|---|---|---|---|---|---|
| | BAU (MT) | StrategyI % change | Strategy II % change | BAU (MCM) | Strategy I % change | Strategy II % change |
| 1994-95 | | | | | | |
| North | 22.07 | 30 77 | 0.01 | 8108 66 | 12 25 | neg |
| South | 17 19 | 22 64 | 0.02 | 2796 16 | 21 64 | neg |
| West | 23 83 | 17 72 | 0 01 | 9375 44 | 4 35 | neg |
| East | 12 82 | 35 29 | 0 01 | 707 90 | 0 00 | neg |
| N East | 2.01 | 31 15 | 0 01 | 2339.16 | 16 89 | neg |
| All India | 80 14 | 25 03 | 0 01 | 23327 31 | 10 58 | neg |
| 1999-00 | | | | | | |
| North | 29.73 | 21 98 | 0 01 | 11515 22 | 17 65 | neg |
| South | 22.31 | 20 56 | 0 01 | 4704 20 | 13 66 | neg |
| West | 30 41 | 17 42 | 0 01 | 15082 63 | 4 55 | neg |
| East | 17 03 | 25 11 | 0 01 | 906 10 | 0 00 | neg |
| N East | 2 62 | 26 37 | 0 01 | 4539 76 | 8 79 | neg |
| All India | 104 82 | 20 40 | 0 01 | 36747 92 | 11 00 | neg |
| 2004-05 | | | | | | |
| North | 38 66 | 26 26 | 3 04 | 13338.67 | 15 31 | -10 98 |
| South | 28 29 | 23 70 | 0 60 | 6268 68 | 10 57 | -3 62 |
| West | 38.62 | 20 70 | 1.63 | 19420 72 | 3 76 | -4 15 |
| East | 22 06 | 28 79 | 0.76 | 1139 39 | 0 00 | 19 92 |
| N East | 3 35 | 32 10 | 2 50 | 6636 51 | 6 05 | -1 70 |
| All India | 134 33 | 24 03 | 1 66 | 46803 97 | 9 40 | -6 06 |
| 2009 10 | | | | | | |
| North | 50 85 | 29 23 | 4 62 | 16052 35 | 13.27 | -18 24 |
| South | 36 48 | 25 17 | 0 93 | 8805 19 | -4 93 | -5 16 |
| West | 49.82 | 21 40 | 2 51 | 26324 96 | -11 48 | -6 12 |
| East | 28 87 | 31 28 | 1 16 | 1444 97 | 0 00 | -31 42 |
| N East | 4 32 | 36 64 | 3 84 | 9969 11 | 4 23 | -2 28 |
| All India | 174.46 | 25 98 | 2.55 | 62596 58 | 0 16 | -9 06 |

Electricity savings are seen to be much larger in the short-term as compared to the long-term. This is because in the long-term we have assumed a larger shift to electrified routes for transportation. The largest savings potential is in the northern region followed by the eastern region up to the turn of the century and the southern region in the next decade. Coal savings are seen to be fluctuating -- increasing from 12 per cent in 1994/95 to 18 per cent in 1999/2000 but reducing again to 16 per cent in the year 2009/10. Firewood savings increase from 4.4 per cent in 1994/95 to close to 9 per cent in 2009/10.

In the case of oil consumption very significant savings in the range of 20 to 25 per cent are noticed under the

conservation strategy and small savings under the alternative energy strategy where essentially LPG is getting replaced by solar cookers and some savings are effected in the consumption of motor spirit and high speed diesel as a result of switching over to compressed natural gas. Correspondingly natural gas consumption in Strategy II actually increases.

A sectoral picture of energy savings is given in table 6.5 below. The largest savings potential is seen to be in agricultural sector for electricity followed by the domestic sector. Coal savings in the range of 15-20% are possible in both the major consuming sectors of power and industry. The maximum reduction in oil consumption is noticed in the transportation sector which has largely been due to the modal shifts that have been assumed.

**Table 6.5.** Energy savings under the 5% growth scenario for 2009-10

| | | | | % Change | |
|---|---|---|---|---|---|
| | BAU | Strategy I | Strategy II | Strategy I | Strategy II |
| ELECTRICITY (TWh) | | | | | |
| Industry | 359 4 | 342 5 | 359 4 | 4 68 | 0 00 |
| Transport | 13 0 | 32 7 | 13 0 | -151.55 | 0 00 |
| Domestic | 94 9 | 86 1 | 94 9 | 9.30 | 0 00 |
| Agriculture | 138 0 | 97 7 | 138 0 | 29 20 | 0 00 |
| TOTAL | 672 6 | 621 2 | 672 6 | 7 64 | 0.00 |
| COAL (MT) | | | | | |
| Industry | 184 9 | 148 8 | 184 9 | 19 49 | 0 00 |
| Power | 389.3 | 324 4 | 389 3 | 16 66 | 0 00 |
| Transport | 3 8 | 11 4 | 3 8 | -198 21 | 0 00 |
| Domestic | 3 3 | 3 0 | 3 3 | 9.20 | 0 00 |
| TOTAL | 645 9 | 541.8 | 645.9 | 16 11 | 0 00 |
| OIL (MT) | | | | | |
| Industry | 33.8 | 30 7 | 33 8 | 8 99 | 0 00 |
| Power | 8 8 | 6 8 | 8 8 | 22 76 | 0.00 |
| Transport | 89 4 | 54 8 | 85 2 | 38 64 | 4 73 |
| Domestic | 21.7 | 19 5 | 21 7 | 10 00 | 0 00 |
| Agriculture | 9 6 | 8 1 | 9 6 | 15.00 | 0 00 |
| TOTAL | 174.5 | 129 1 | 170 0 | 25 98 | 2 55 |
| Natural Gas (BCM) | | | | | |
| CNG | | | 5 7 | | |
| Industry | 23.9 | 22 0 | 23 9 | 8 02 | 0 00 |
| Power | 38.7 | 40 5 | 38 7 | -4 70 | 0 00 |
| Total | 62 6 | 62 5 | 68 3 | 0 16 | -9 06 |
| FIREWOOD (MT) | | | | | |
| Rural | 153.3 | 153 3 | 136 9 | 0 00 | 10.74 |
| TOTAL | 184 4 | 184 4 | 167 9 | 0 00 | 8 93 |

Energy savings for the 6% growth scenario are given in Table 6.6. The percentage savings are quite different from those in the 5% growth scenario as the mix of industries is significantly different.

**Table 6.6.** Energy savings under the 6% growth scenario for 2009-10

| | BAU | Strategy I | Strategy II | % Change Strategy I | % Change Strategy II |
|---|---|---|---|---|---|
| Electricity (TWh) | 727 6 | 668.8 | 727 6 | 8 07 | 0 00 |
| Coal (MT) | 768 9 | 671.6 | 768 9 | 12 66 | 0 00 |
| Oil (MT) | 187 4 | 141 6 | 182 8 | 24.43 | 2 44 |
| Natural gas (BCM) | 70 2 | 65 9 | 75 9 | 6 10 | -8 08 |
| Firewood (MT) | 175 6 | 175 6 | 166 8 | 0 00 | 5 03 |

6.4.2 Power sector

With the improvements in the power sector in the conservation strategy, and given the power demand forecasts, the required increases in generation capacity are considerably lower than in the BAU strategy of development. However, additions of windfarms and small hydropower capacity are assumed to be as in the BAU strategy. In the 5% per annum GDP growth case, the capacity additions in successive five-year intervals from 1990/91 to 2009/10 are given in Table 6.7. In the 6% per annum GDP growth case, the additions to despatchable generating capacity during the four successive five year intervals from April 1990 to March 2010 are 25942 MW, 27440 MW, 32930 MW and 47390 MW respectively. It may be noted that it is assumed that coal will be washed for power generation in Northern, Western and Southern Regions only -- where in general, it is transported over relatively long distances by rail.

In the 5% GDP growth case, about 40,100 MW of generation capacity is added during the 1990s, compared to about 54,900 MW in the BAU strategy. From 2000/01 to 2009/10, the capacity additions are 75,500 MW, compared to over 86,200 MW in the BAU strategy. However, an important difference is that even with lower capacity additions in this strategy, the projected power shortages (both in terms of peak and energy) are rather small (Table 6.8).

Additions of conventional power generating capacity in the alternative energy strategy will be the same as in the BAU strategy. However, owing to the additions of RET capacity, power shortages will reduce considerably from BAU levels (Table 6.8), and grid expansion requirements at 33kV and lower voltage levels will be slightly higher than in the BAU strategy.

**Table 6.7.** Power Generating Capacity Additions in 5% GDP Growt Case (MW) - Strategy I

| | April 1990 to March **1995** | April 1995 to March **2000** | April 2000 to March **2005** | April 2005 March **2010** |
|---|---|---|---|---|
| **Northern Region** | | | | |
| Hydro | 1768 | 4947 | 4429 | 2420 |
| TPS | 840 | 1370 | - | 500 |
| TPS/Washery | 210 | 630 | 1630 | 4890 |
| GT/CCP | 1528 | 715 | 300 | 475 |
| Nuclear | 470 | 470 | 1000 | 1589 |
| Total | 4816 | 8132 | 7359 | 9874 |
| **Western Region** | | | | |
| Hydro | 1303 | 250 | 1223 | 1900 |
| TPS | 1550 | 2330 | 3140 | 1840 |
| TPS/Washery | - | 420 | 2360 | 5900 |
| GT/CCP | 2200 | 1745 | 900 | 3530 |
| Nuclear | 470 | - | 500 | 795 |
| Total | 5523 | 4745 | 8123 | 13965 |
| **Southern Region** | | | | |
| Hydro | 1145 | 1000 | 598 | 1431 |
| TPS | 1260 | 2100 | 4610 | 3300 |
| TPS/Washery | - | - | 210 | 3860 |
| GT/CCP | 560 | 478 | 290 | 1106 |
| Nuclear | - | 470 | 940 | 1494 |
| Total | 2965 | 4048 | 6648 | 11191 |
| **Eastern Region** | | | | |
| Hydro | 1371 | 82 | 1100 | 2604 |
| TPS | 2940 | 3150 | 4050 | 5210 |
| Total | 4311 | 3232 | 5150 | 7814 |
| **North-eastern Region** | | | | |
| Hydro | 371 | 222 | 651 | 2145 |
| GT/CCP | 712 | 1062 | 1000 | 1589 |
| Total | 1083 | 1284 | 1651 | 3734 |
| **All India** | | | | |
| Hydro | 5957 | 6500 | 8000 | 10500 |
| TPS | 6590 | 8950 | 11800 | 10850 |
| TPS/Washery | 210 | 1050 | 4200 | 14650 |
| GT/CCP | 5000 | 4000 | 2490 | 6700 |
| Nuclear | 940 | 940 | 2440 | 3878 |
| Total | 18697 | 21440 | 28930 | 46578 |

**Table 6.8.** Peak Demand and Energy Shortages

| | 1994/95 | 1999/00 | 2004/05 | 2009/10 |
|---|---|---|---|---|
| | | Strategy I | | |
| **5% GDP Growth Case** | | | | |
| % Peak shortage | -0.25 | -0.04 | -0.03 | -0.07 |
| % Energy shortage | -0.57 | 0.41 | 2.56 | 1.88 |
| **6% GDP Growth Case** | | | | |
| % Peak shortage | 2.24 | 0.45 | 0.52 | 0.68 |
| % Energy shortage | -0.59 | -2.50 | -0.59 | 0.28 |
| | | Strategy II | | |
| **5% GDP Growth Case** | | | | |
| % Peak shortage | 9.01 | 2.49 | 2.27 | 1.74 |
| % Energy shortage | 6.02 | -0.62 | 0.61 | 0.76 |
| **6% GDP Growth Case** | | | | |
| % Peak shortage | 17.83 | 11.23 | 9.18 | 3.08 |
| % Energy shortage | 14.01 | 6.73 | 5.40 | 0.32 |

In the conservation strategy, investment levels in the power sector are considerably lower than in the BAU strategy, even if washery costs are added (Table 6.9). Capital costs of a washery are estimated at $3.57 million/mtpa and a capacity utilization factor of 90% is assumed. For T & D loss reduction, it is assumed that only one-third of the loss reduction achieved in any year will be technical losses -- the rest will be due to reduction of pilferage, improved billing procedures, better metering etc., which entail little investment.

In the alternative energy strategy, investment levels are different from the BAU strategy only to the extent more windfarms and small hydro capacity are installed.

The fuel inputs required for power generation in both the strategies have been incorporated in the energy demand projections.

**Table 6.9.** Investment requirements in the Power Sector ($ million)

| | 1990/91 to 1994/95 | 1995/96 to 1999/00 | 2000/01 to 2004/05 | 2005/06 to 2009/10 |
|---|---|---|---|---|
| | | Strategy I | | |
| 5% GDP growth case | | | | |
| Washeries | 2 51 | 12 53 | 50.11 | 174.79 |
| Despatchable generation tech | 11654 | 14512 | 20887 | 34746 |
| Renewable generation tech | 308 | 441 | 574 | 983 |
| T & D Systems expansion | 7769 | 9675 | 13925 | 23164 |
| T & D Loss reduction | 0 | 273 | 1333 | 2367 |
| Total | 19733 | 24914 | 36769 | 61434 |
| 6% GDP growth case | | | | |
| Washeries | 5 01 | 17 54 | 75 17 | 226 7 |
| Despatchable generation tech | 16056 | 18606 | 23626 | 35103 |
| Renewable generation tech | 308 | 441 | 574 | 983 |
| T & D systems expansion | 10704 | 12404 | 15751 | 23402 |
| T & D loss reduction | 0 | 313 | 1468 | 2454 |
| Total | 27074 | 31781 | 41494 | 62169 |
| | | Strategy II | | |
| 5% GDP growth case | | | | |
| Total investment | 26428 | 34663 | 43861 | 70215 |
| of which | | | | |
| -on RETs | 308 | 758 | 1250 | 1700 |
| 6% GDP growth case | | | | |
| Total investment | 27074 | 37262 | 49359 | 82830 |
| of which | | | | |
| -on RETs | 308 | 758 | 1250 | 1700 |

### 6.4.3 Coal and lignite situation

The indigenous production of coking and non-coking coals as well as lignite remain the same as in the BAU strategy, and so do investment requirements (see chapter III). However, the demand, both for power generation and other uses is considerably reduced in the conservation strategy. Table 6.10 gives the regional coal availability situation vis-a-vis production in both the low and high GDP growth cases. Again, the Eastern Region will be supplying both coking and non-coking coals to other regions of the country. If production levels are maintained as in the BAU strategy, there will be an overall surplus of non-coking coals in the low GDP growth case. In the high GDP growth case, the overall coal deficits are significantly lower than in the BAU strategy. Nevertheless, India would still need to undertake a massive

effort to develop port facilities.

In the alternative energy strategy, coal and lignite demand and supply situations remain unchanged from BAU strategy levels.

**Table 6.10.** Regional coal imports - Strategy I

(MT per year)

| | 1994/95 | 1999/00 | 2004/05 | 2009/10 |
|---|---|---|---|---|
| **Non-coking Coal (5% GDP Growth Case)** | | | | |
| NR | 57.45 | 67.42 | 79.21 | 105.01 |
| WR | 6.04 | 5.80 | 20.37 | 47.01 |
| SR | 5.68 | 7.43 | 20.22 | 44.35 |
| ER | -88.89 | -147.50 | -206.97 | -279.08 |
| NER | -0.50 | -1.62 | -0.83 | 3.55 |
| INDIA | -20.22 | -68.47 | -88.00 | -79.16 |
| **Non-coking Coal (6% GDP Growth Case)** | | | | |
| NR | 64.59 | 79.79 | 98.08 | 134.51 |
| WR | 12.32 | 23.18 | 48.96 | 93.90 |
| SR | 14.03 | 27.25 | 51.17 | 88.49 |
| ER | -87.35 | -144.01 | -201.70 | -275.35 |
| NER | -0.50 | -1.59 | -0.71 | 3.83 |
| INDIA | 3.09 | -15.38 | -4.20 | 45.38 |

### 6.4.4 Oil Situation

In the conservation strategy, both the indigenous crude oil production and refining capacity and complexity remain the same as in the BAU strategy; so do investment levels. However, as the demands for various products are relatively lower in the conservation strategy, India's self-sufficiency in refining capability increases. In the low GDP growth case, refining capacity (as a percentage of demand), increases to nearly 100% by 2009/10. However, as the capacity utilization of refineries is assumed to be 90% (as in the BAU strategy) and refinery losses at 6%, total refinery production will be considerably lower than demand. In the high GDP growth case, refining capacity accounts for about 91% of the demand in 2009/10. Table 6.11 summarises the results. It is evident that India will continue to import middle distillates as well as heavy ends. However, there will be small surpluses of light distillates for exports.

The demands for refined products in the alternative energy strategy are marginally, below that in the BAU strategy. Therefore, the crude import levels will be the same as in the

BAU strategy but total product import requirements somewhat less -- for products that are exported, the exportable quantities increase somewhat. However, the deficits of middle distillates (particularly HSD) remain high.

**Table 6.11.** Oil supply situation

(MT per annum)

| | Strategy I | | | | Strategy II | | | |
|---|---|---|---|---|---|---|---|---|
| | 1994/95 | 1999/00 | 2004/05 | 2009/10 | 1994/95 | 1999/00 | 2004/05 | 2009/10 |
| 5% and 6% GDP Growth Case | | | | | | | | |
| Refining Capacity | 61 8 | 81 6 | 105 3 | 138 4 | 61 8 | 81 6 | 105 3 | 138 4 |
| Crude Throughput | 55 6 | 73 4 | 94 7 | 124.5 | 55 6 | 73 4 | 94 7 | 124.5 |
| Refinery Output | | | | | | | | |
| -Total | 52.3 | 69 0 | 89 0 | 117 1 | 52 3 | 69 0 | 89 0 | 117 1 |
| -Light Distillates | 10 9 | 14 7 | 19 3 | 25 8 | 10 8 | 14 7 | 19 3 | 25 8 |
| -Middle Distillates | 29.1 | 39 1 | 51 1 | 68 0 | 29 1 | 39.1 | 51.1 | 68 0 |
| -Heavy Ends | 12 3 | 15 2 | 18.6 | 23 4 | 12.3 | 15 2 | 18 6 | 23 4 |
| 5% GDP Growth Case | | | | | | | | |
| Net Imports | | | | | | | | |
| -Crude | 20 1 | 30 2 | 41 4 | 54 0 | 20 1 | 30 2 | 41 4 | 54.0 |
| -Light Distillates | 0 4 | -1 3 | -3 2 | -5 5 | 1 4 | 0 7 | 0 2 | -0 8 |
| -Middle Distillates | 7 7 | 16 4 | 16 3 | 15 0 | 25 9 | 33 8 | 39.9 | 47 7 |
| -Heavy Ends | 3 9 | 4 7 | 6.8 | 11 9 | 5 2 | 7.3 | 10.9 | 16.8 |
| 6% GDP Growth Case | | | | | | | | |
| Net Imports | | | | | | | | |
| -Crude | 18 0 | 25 5 | 32 7 | 38 5 | 18 0 | 25 5 | 32 7 | 38 5 |
| -Light Distillates | 0.7 | -0 04 | -1 9 | -5 5 | 2 0 | 1 9 | 1.3 | -1 1 |
| -Middle Distillates | 9 5 | 20 4 | 32 1 | 25 4 | 27.8 | 38 1 | 56 2 | 58 8 |
| -Heavy Ends | 4 9 | 6 6 | 9 3 | 14 7 | 5 8 | 8 3 | 12 6 | 19 6 |

6.4.5 Gas situation

In the conservation strategy, the demand for natural gas is lower than in the BAU strategy -- and so is gas production from free gas fields. The production of associated gas remains as in the BAU strategy. All natural gas requirements will be met through indigenous sources.

Table 6.12 gives the capital investment requirement for pipelines on land and off-shore. Owing to the fact that the gas demand in 2009/10 is relatively lower in the conservation strategy, the total capital requirements over the twenty year time period are less. However, the investment in one of the five-year intervals for which data are shown may be more -- depending on the additional gas demand during that particular five year period.

**Table 6.12.** Investment for Natural Gas Pipelines - Strategy I

| | 1990/91 to 1994/95 | 1995/96 to 1999/00 | 2000/01 to 2004/05 | 2005/06 to 2009/10 |
|---|---|---|---|---|
| 5% GDP Growth Case | | | | |
| Pipelines ($ million) | | | | |
| -onland | 1725 | 2108 | 1727 | 3576 |
| -offshore | 1294 | 740 | 1002 | 2530 |
| -Total | 3019 | 2848 | 2729 | 6106 |
| 6% GDP Growth Case | | | | |
| Pipelines ($ million) | | | | |
| -onland | 2285 | 2205 | 1904 | 3354 |
| -offshore | 1468 | 974 | 1366 | 3354 |
| -Total | 3754 | 3179 | 3270 | 6708 |

Owing to a substantial increase in gas demand in the alternative energy strategy, indigenous gas production is considerably larger than in the BAU strategy. Even in this strategy, it is possile to meet additional gas requirements by increasing the production from free gas fields. The investment levels required for gas pipelines are also concommitantly higher than in the BAU strategy, as shown in Table 6.13.

**Table 6.13.** Investment for natural gas pipelines - Strategy II

| | 1990/91 to 1994/95 | 1995/96 to 1999/00 | 2000/01 to 2004/05 | 2005/06 to 2009/10 |
|---|---|---|---|---|
| 5% GDP Growth Case | | | | |
| Pipelines ($ million) | | | | |
| -onland | 2164 | 2389 | 2295 | 3316 |
| -offshore | 1294 | 740 | 1002 | 2530 |
| -Total | 3458 | 3129 | 3297 | 5846 |
| 6% GDP Growth Case | | | | |
| Pipelines ($ million) | | | | |
| -onland | 2380 | 2619 | 2663 | 3859 |
| -offshore | 1468 | 974 | 1366 | 3354 |
| -Total | 3848 | 3593 | 4028 | 7212 |

## 6.5 Combination of Strategies I and II

The impact of efficiency improvements, demand management, fuel substitution and the rapid penetration of RETs considered in the above strategies are included here.

**Table 6.14.** Energy savings from implementing both the above strategies (5% GDP growth)

| | Unit | BAU | Strategies I & II | % change |
|---|---|---|---|---|
| Electricity | TWH | 673 | 621 | 7.64 |
| Coal | MT | 646 | 542 | 16.11 |
| Oil | MT | 175 | 125 | 28.41 |
| Natural gas | Bcm | 63 | 68 | -8.90 |
| Firewood | MT | 184 | 168 | 8.93 |

Total energy savings in the demand sector, are for the 5% GDP growth case as given in Table 6.14. In terms of million tonnes of oil equivalent of saving, this works out to approximately 50 MTOE/annum. Investment requirements for affecting the above savings work out to roughly Rs. 900 billion. Energy savings under the 6% growth scenario are given in Table 6.15.

**Table 6.15.** Energy savings from implementing both the above strategies (6% GDP growth)

| | BAU | Strategies I & II | % change |
|---|---|---|---|
| Electricity | 728 | 669 | 8.07 |
| Coal | 769 | 672 | 12.66 |
| Oil | 187 | 137 | 26.88 |
| Natural gas | 70 | 72 | -1.98 |
| Firewood | 176 | 167 | 5.03 |

<u>Power Availability</u>: With additions to despatchable generation capacities as in Strategy I and RET capacities as in strategy II, the peak power and energy deficits disappear in most cases (Table 6.16) -- an indication that the power system reliability will be good.

Investments are correspondingly higher than in the conservation strategy and are \$19733 million, \$25231 million, \$37445 million and \$62151 million (including investment in washeries) in the 5% GDP growth case in successive five year intervals from 1990/91 to 2009/10. In the 6% GDP growth case, the corresponding investment levels are \$27074 million, \$32098 million, \$42169 million and \$62886 million respectively.

**Table 6.16.** Combination strategy -- Peak power and energy deficits

| | 1994/95 | 1999/00 | 2004/05 | 2009/10 |
|---|---|---|---|---|
| **5% GDP Growth Case** | | | | |
| % peak shortages | -0.25 | -0.09 | -0.10 | 0.01 |
| % energy shortages | -0.57 | 0.36 | 2.53 | 2.02 |
| **6% GDP Growth Case** | | | | |
| % peak shortages | 2.24 | 0.41 | 0.46 | 0.63 |
| % energy shortages | -0.59 | -2.57 | -0.75 | -0.09 |

Coal: Coal requirements remain as in the conservation strategy. So do coal production levels, and consequently regional and national shortages and surpluses.

Oil: Oil demands reduce from the conservation strategy levels, and so do the net import requirements of various products (Table 6.17). Major shortages of middle-distillates (particularly HSD) however, continue.

As indigenous crude production levels and refining capacity (along with its utilization and complexity) remain as in other strategies, so do crude oil imports.

**Table 6.17.** Combination strategy -- net petroleum imports (MT per annum)

| | 1994/95 | 1999/00 | 2004/05 | 2009/10 |
|---|---|---|---|---|
| **5% GDP Growth Case** | | | | |
| Crude | 20.1 | 30.2 | 41.4 | 54.0 |
| Light Distillates | 0.3 | -1.4 | -3.6 | -6.2 |
| Middle Distillates | 7.7 | 16.4 | 16.3 | 15.0 |
| Heavy Ends | 3.9 | 4.7 | 6.8 | 11.9 |
| **6% GDP Growth Case** | | | | |
| Crude | 19.0 | 25.5 | 32.7 | 38.5 |
| Light Distillates | 0.6 | -0.2 | -2.3 | -6.1 |
| Middle Distillates | 9.5 | 20.4 | 30.1 | 21.4 |
| Heavy Ends | 4.9 | 6.6 | 9.3 | 14.7 |

Gas: Compared to the conservation strategy, there is a significant increase in natural gas demand. This additional gas demand will be met by increasing the output from free gas fields. In fact, the free gas production requirements remain substantially below the free gas production potential in the

low GDP growth case, although the latter will only be marginally higher than the former in the high GDP growth case. Investment requirements for gas pipelines are given in Table 6.18.

**Table 6.18.** Combination Strategy -- Investments Required Natural Gas Pipelines

| | 1990/91 to 1994/95 | 1995/96 to 1999/00 | 2000/01 to 2004/05 | 2005/06 to 2009/10 |
|---|---|---|---|---|
| 5% GDP Growth Case | | | | |
| Pipelines ($ million) | | | | |
| -onland | 1725 | 2108 | 2232 | 4081 |
| -offshore | 1294 | 740 | 1002 | 2530 |
| -Total | 3019 | 2848 | 3234 | 6611 |
| 6% GDP Growth Case | | | | |
| Pipelines ($ million) | | | | |
| -onland | 2285 | 2205 | 2409 | 3859 |
| -offshore | 1468 | 974 | 1366 | 3354 |
| -Total | 3754 | 3179 | 3775 | 7213 |

**Appendix 6.1**

The use of washed coal has several implications on the cost and performance of TPS units. Empirical relationships have been developed, on the assumption that a TPS unit normally uses coal with a gross calorific value (GCV) of 4500 kCal/kg, and ash content (AC) of 36.6%. In fact, Bharat Heavy Electricals Ltd. (BHEL) manufactures boilers designed to burn such coal. As coal of GCV of 4000 kCal/kg has AC of 40%, the following relationship emerges :

GCV = 10000 - 150.AC ------------------------------- (1)

According to Natarajan and Suri (1982), a 15% increase in ash content results in an increase in the boiler cost by 9% and of the coal handling plant (CHP) plus ash handling plant or AHP (including electrostatic precipitators or ESP) by 10%. These observations form the basis for the following relationships:

KBwash = KB.(4500/GCV)^(0.16) -------------------(2)

KCwash = KC.(4500/GCV)^(0.177) ------------------(3)

where KB = boiler cost in a TPS unit using normal unwashed non-coking coal (Rs./kW);

KBwash = boiler cost in a TPS unit using washed coal (Rs./kW);

KC = Capital cost of CHP plus AHP (excluding ESP) in a TPS unit using normal unwashed non-coking coal (Rs./kW); and KCwash = Capital cost of CHP plus AHP (excluding ESP) in a TPS unit using washed coal (Rs./kW).

For estimating reductions in capital costs of TPS units, it is further assumed that the boiler comprises 33% of total capital costs and the CHP plus AHP (excluding ESP) about 17% of the total costs of a TPS unit using unwashed non-coking coal.

Tests of using washed coal in TPS units were made at the Satpura TPS (Western Region). These tests showed that for a GCV increase of 1500 kCal/kg (12% coal reduction), the boiler efficiency increases by about 3%. As Bharat Heavy Electricals Ltd. (BHEL) manufactures boilers having an efficiency of 86%, the following empirical relationship may be derived:

$$EBwash = 0.86*(GCV/4500)^{(0.12)} \text{-------------} (4)$$

Where EBwash = efficiency of boiler using washed coal (fraction).

Further, BHEL also guarantees a heat rate of 2009 kCal/kWh for its units, which implies that:

$$HRwash = 2009/EBwash \text{----------------------} (5)$$

Where HRwash = heat rate of a TPS unit running on washed coal.

Other assumptions that are made are:

(i) TPS availability increases by 1% as AC decreases by 1% -- this underestimates the claims made in India;#

(ii) Auxiliary consumption reduces by 0.06% for every 1% reduction in AC; and

(iii) Oil support reduces by 0.715 ml/kWh for every 1% decrease in AC.

---

# It is reported that at the Chandrapur TPS in Maharashtra (Western Region), plant availability increased by about 2% for every 1% reduction in AC. The Satpura trials showed even more startling results --plant availability increased by 3% for every 1% reduction in AC. However, we assume a conservative estimate of a 1% increase in availability for every 1% reduction in ash content, as claimed in the US (See Meier and Thukral, 1990).

CHAPTER
7

# Economic Analysis of alternative strategies

## 7.1 Introduction

Costs associated with various development strategies in the year 2009/10 are presented in this chapter. These include : (i) direct economic costs associated with the production and supply of various energy sources; (ii) direct economic costs associated with various demand management measures; and (iii) environmental costs associated with energy supply and demand management. In addition to these costs at the national/regional levels, economic and environmental costs in two areas of stress (Singrauli and Delhi) are also presented.

A social discount rate of 12% per annum is used to present the economic costs for both supply and demand side measures. For environmental costing, various discount rates are used.

## 7.2 Assumptions

### 7.2.1 Demand side

The demand side investments for the BAU strategy are chosen as the reference level, and therefore only incremental investments for the set of demand management measures that comprise the alternative strategies are included. Some general assumptions for the economic analysis are as follows:

In the domestic sector, the comparative economic analysis of fluorescents and incandescents is carried out by taking the average market price of installing the two types of connections. The price of each of the component parts and its operating life is given in Table 7.1. The cost of electricity is taken to be US$ 0.08/kWh.

For improved refrigerators, the market prices of the old and new models of refrigerators are taken as US$ 333 and US$ 417 respectively, with the mean operating life of 20 years. In case of both the models, annual maintenance costs are assumed to be 1 per cent of the capital cost.

**Table 7.1.** Assumptions regarding the market price and operating life of fluorescent and incandescents.

| | Market price (US$/unit) | Operating life (years) |
|---|---|---|
| Fluorescents | | |
| - Holder | 2.20 | 15 |
| - Tube | 1.95 | 2 (1) |
| - Choke | 4.20 | 5 |
| Incandescents | | |
| - Holder | 1.70 | 10 |
| - Bulb | 0.50 | 0.4 (1) |

(1) These are estimated by assuming the average life of a fluorescent lamp to be 5000 hours, incandescent bulb as 1000 hours and the average daily use to be about 7 hours.

For the option of a portion of urban residential cooking energy demand to be met by solar cookers, it is assumed that the solar cookers would substitute only 20% of the energy demand for cooking in the owner households. This is because a solar cooker is not a perfect substitute for conventional cooking devices owing to its unsuitability for frying or making chappatis (Indian wheat bread) which are essential components of an Indian meal. The capital cost is assumed to be US$ 60 as against its market price which is much lower due to the subsidy offered by the Government. The annual O&M is taken as 2.5% of the capital and an average operating life of 10 years.

For the combined option of using biogas with improved cookstoves, the cost of construction of a family size biogas plant ($2m^3$ capacity) is taken to be US$ 278 and that of an improved cookstove to be US$ 3.9, with O&M costs of 0.5% and 0.67% of capital respectively. The life of a biogas plant is assumed to be 20 years and an improved cookstove to be 5 years.

In the transport sector, all existing buses are assumed to be phased out with the introduction of urban buses. The additional capital cost is taken as US$ 0.5 million, O&M at 5 per cent of the capital and a life of 20 years.

For road improvements, the investments are phased out at the rate of 40%, 30%, 20% and 10% of a total of US$ 8.7 billion for the years 1994/95, 1999/00, 2004/05 and 2009/10 respectively. O&M costs are assumed at 5 per cent of the capital cost.

For the shift from road to rail option, the investment (US$ 50 billion) is assumed to be phased similar to the strategy of road improvements. The life of the system is assumed to be 35 years and O&M cost at 2.5 per cent.

The net investment required is derived after deducting the investment removed from the road sector (swing effect) from the gross investment in railways.

The metro option has an average investment of US$ 1.3 billion each, the phasing of which is similar to the strategy of road improvements. Interest during construction (IDC) has been included at 12%. It is assumed that metro systems start functioning from the year 2000/01 and hence the swing effect i.e. shift from road transport modes to metro will be observed only after 2000/01. Based on the pkm the metro system would satisfy, it is assumed that it would displace 10% of cars, 10% of three wheelers, 45% of two wheelers and 35% of buses in each of the cities. The life of the system is assumed to be 35 years and O&M costs are placed at 5% of the capital cost. The fuel consumption of the metro system is assumed to be 9 watt-hours per pkm [8kCal/pkm (30kCal/pkm taking in to account the generation and T&D efficiencies)] as against 92kCal/pkm for a bus.

The assumptions made for the CNG option is that the O&M costs are 10 per cent of the capital cost and average life of the system is 35 years.

In the industrial sector, conservation measures are considered for the iron and steel, petrochemicals and cement industries. O&M costs for process changes are assumed to be 2.5% of the capital. Life time of equipment is taken as 20 years.

The assumptions in the agricultural sector are as follows. The cost of replacing footvalve and suction pipeline is $32 ($46 with delivery line included) per pump-set. The life of both the options is 5 years.

The cost of replacing the pump is assumed to be $152 and has a life of 7 years. The cost of replacing the motor is $380 and has a life of 15 years.

### 7.2.2 Supply side

The basic objective is to compute both capital costs of investing in various supply projects during the 1990/91 through 2009/10 period (which may be annuitized over their economic life times) plus fixed and variable operating costs incurred in the year 2009/10. Net fuel import bills are also included.

Various types of power generating capacity and other energy supply establishments have gestation periods of several years during which the investment is made. Although the actual phasing of investment is not accounted for in the economic analysis, the gestation periods are used to compute the interest during construction (IDC) at a social discount rate of 12% per annum. Further, the capital costs are annuitized over the economic lifetimes of these assets. Table 7.2 lists the gestation periods, IDC factors, economic life times and capital recovery factors (CRF) for various energy supply infrastructure requirements.

**Table 7.2.** IDC factors* and CRF for energy supply infrastruct

| | Gestation period (years) | IDC factor* | Economic life (years) | CRF |
|---|---|---|---|---|
| **Power Plant** | | | | |
| - Hydro | 8 | 1.5036 | 50 | 0.120 |
| - TPS | 6 | 1.3382 | 30 | 0.124 |
| - GT/CCP | 3 | 1.1236 | 30 | 0.124 |
| - Nuclear | 12 | 1.8983 | 30 | 0.124 |
| - Windfarms | 1 | 1.0 | 20 | 0.133 |
| - Small Hydro | 1 | 1.0 | 30 | 0.124 |
| **Refinery** | | | | |
| - with FCC | 6 | 1.3382 | 30 | 0.124 |
| - with HCU | 6 | 1.3382 | 30 | 0.124 |
| LPG Extraction | 2 | 1.06 | 30 | 0.124 |
| **Coal Mining** | | | | |
| - OC | 5 | 1.2625 | 35 | 0.122 |
| - UG | 8 | 1.5036 | 35 | 0.122 |
| **Gas Pipelines** | | | | |
| - On land | 2 | 1.06 | 30 | 0.124 |
| - Offshore | 2 | 1.06 | 30 | 0.124 |

* Ratio of IDC plus capital investment to capital investment.

Fixed O&M costs (as a percentage of capital investment plus IDC) are assumed as follows : (i) 1% for large hydro projects; (ii) 2.5% for coal based TPS units, using both washed and unwashed coals; (iii) 2% for GT/CCP units; (iv) 2.5% for nuclear power stations; (v) 3.33% for windfarms; (vi) 2% for small hydro projects; (vii) 5% for LPG extraction plants; (viii) 7.5% for natural gas pipelines, both onland and offshore; and (ix) 10% for exploratory drilling and

oil/gas field developmental activities. The O&M costs of refineries with FCC units are taken at $4870/tonne of crude feed, and for those with HC units at $15400/tonne of crude feed. Likewise, open-cast and underground coal/lignite mining projects are assumed to entail a cost of $7.4/tonne and $14.1/tonne of output respectively.

Owing to the fact that there will be significant shortages of coal and oil, foreign exchange requirements for fuel imports are also estimated. The following assumptions are made: (i) border prices of coal and crude oil are the same in calorific value terms; (ii) border price of crude oil as $20/barrel in 1990/91; (iii) border price of fuel oils and bitumens as $18/barrel in 1990/91; (iv) border prices of other refined products (motor-spirits, naphtha, diesel oils, kerosenes etc.) were $22/barrel in 1990/91; and (v) prices of crude oils and refined products increase in real terms to the year 2009/10, at the rate of 1% per annum.

For computing costs of supplying coal and fuel oil to power stations in various regions, the average distances for transportation by railways and associated cost of freight transport per tonne of fuel (as obtained from the Railway Board) are given in Table 7.3. As fuel oils will be imported at the margin, the distances are as measured from the port of import. For coal and lignite transportation, distances from mines are considered. Natural gas costs for power generation are assumed to be at par with fuel oil costs (in calorific value terms) in each Region.

For nuclear power stations, annual make-up of heavy water and natural uranium are taken at 34 kg/MW and 140 kg/MW of installed capacity respectively; and their costs at $1335/kg and $204/kg respectively.

It is assumed that various types of consumers will install and use standby dg (diesel generator) sets to mitigate the effects of power shortages. The costs of dg sets are as follows: (i) capital cost plus installation charges of $350/kW; (ii) fixed annual costs (including salaries/wages and maintenance charges) of $44.6/kW; and (iii) diesel and lubricating oil consumption at the rates of 0.3 litres/kWh and 0.006 litres/kWh respectively.

The economic life time of dg sets is taken as 15 years, and capacity utilization at 500 kWh/kW per annum. For sake of convenience, only the border prices of diesel and lubricating oils are considered -- an implicit assumption being that grid power is traded between regions and shortages arise largely in the coastal areas. Costs incurred in using dg sets give the lower bound estimates of costs of power shortages.

In addition to the assumptions listed above, the capital investment requirement norms for various types of energy supply projects, as given in Chapters 3 and 4, are used for computing economic costs for various development strategies.

**Table 7.3.** Fuel transportation costs to TPS units in various regions

| | Coal/Lignite | | Fuel Oil | |
|---|---|---|---|---|
| | Distance (km) | Transportation Costs ($/tonne) | Distance km) | Transportation Costs ($/tonne) |
| NR | 550 | 38.87 | 1000 | 44.60 |
| WR | 400 | 28.27 | 200 | 10.01 |
| SR | 300 | 21.20 | 400 | 18.20 |
| ER | 150 | 10.60 | 300 | 14.18 |
| NER | 200 | 14.10 | 100 | 5.88 |

## 7.3 BAU strategy

Owing to the fact that the demand side investments in the BAU strategy are made as the reference level, only supply side investments are presented below.

Economic costs associated with the BAU strategy, under both 5% and 6% per annum GDP growth assumptions, are summarized in Table 7.4. Total costs are estimated at $128.4 billion and $145.5 billion respectively. Costs in the high GDP growth case are higher by about 13.3% over the lower GDP growth rate case.

The major cost components in the low GDP growth case are power supply (41.1%), hydrocarbon exploration and field development (25.8%), and fuel imports (18.1%). The cost shares of these components are very similar in the high GDP growth case, at 40.5%, 24.0% and 22.3% respectively. The share of the fuel import bill rises in the latter case essentially because indigenous coal and lignite production remain the same as in the former. As net imports of middle-distillates account for over 43% of the fuel import bill in the low GDP growth case, and over 37% in the high GDP growth case, the need to curtail their demand is reiterated.

The region-wise break-up of economic costs are given in Appendices 7.1 and 7.2 for the low and high GDP growth rate cases respectively. The largest share of the costs are incurred in the Western Region, due largely to the high share of oil/gas exploration and development activity there. Costs

are least in the Northeastern region, and reflect the low levels of energy requirements there.

Costs incurred directly in foreign exchange (for fuel imports alone) are anticipated to rise to $23.2 billion in the low GDP growth case and $32.4 billion in the high GDP growth case. In comparison, the net fuel import bill in 1989/90 (the most recent year for which reliable data are available), was less than $3.3 billion; and total imports were only $20.8 billion. The rapid rise in foreign exchange requirements for fuel imports indicates the need to pursue alternative development strategies.

**Table 7.4.** Economic costs of energy supply in the BAU strategy ($ million, 90/91 prices)

| | Low GDP Growth Case | High GDP Growth |
|---|---|---|
| Total | 128421 | 145538 |
| Coal mining | 10809 | 10809 |
| Lignite mining | 671 | 671 |
| Hydrocarbon exploration | 27645 | 29023 |
| Hydrocarbon field development | 5477 | 5963 |
| Refining | 2729 | 2729 |
| LPG extraction | 220 | 289 |
| Natural gas pipelines | | |
| - on land | 1932 | 2219 |
| - offshore | 1362 | 1624 |
| Power supply | 52772 | 58888 |
| Power shortages | 1556 | 893 |
| Net fuel imports | 23248 | 32429 |
| - Coal | 2295 | 11827 |
| - Crude oil | 9375 | 6678 |
| - Refined products | 11578 | 13924 |

## 7.4 Alternative strategies

### 7.4.1 Demand side

#### 7.4.1.1 Alternative strategy I

**Domestic sector**

Energy efficient lighting: Table 7.5 gives the incremental annual costs (inclusive of fuel costs) both in aggregate and per household terms, and the associated electricity savings

achieved by replacing incandescent bulbs with fluorescent lamps in the year 2009-10.

**Table 7.5.** Economic analysis of energy efficient lighting

| Region | Net Annual Savings (million US$) | Annual savings per household (US$) | Annual electricity savings (TWh) |
|---|---|---|---|
| **5 % GDP growth rate** | | | |
| North | 126.38 | 5.48 | 1.46 |
| South | 20.64 | 1.01 | 0.18 |
| West | 70.62 | 3.83 | 0.82 |
| East | 26.69 | 2.32 | 0.32 |
| North-east | 5.82 | 2.97 | 0.07 |
| All India | 250.15 | | 2.85 |
| **6 % GDP growth rate** | | | |
| North | 88.33 | 4.06 | 1.02 |
| South | 16.57 | 0.86 | 0.15 |
| West | 103.14 | 5.93 | 1.2 |
| East | 22.52 | 2.08 | 0.27 |
| North-east | 4.99 | 2.70 | 0.06 |
| All India | 235.55 | | 2.7 |

The results clearly indicate that owing to a longer life and greater luminous efficacy fluorescents would result in substantial savings, both in terms of costs as well as energy. These get translated to annual financial savings varying in the range of US$ 1 to US$ 6/household in different regions of the country. Moreover, the savings in capital that would accrue from this measure are estimated to be of the order of US$ 71 million (5% GDP growth rate) and US$ 70 million (6% GDP growth rate).

Improved refrigerators: For domestic refrigerators, the analysis of economic viability of new and more energy efficient models has been carried out by assuming that these would replace at least 25% of the total stock in the long run, beginning 1999-2000. In the preceding period, from 1989-90 to 1999-2000, about 30% conservation in energy would be achievable through regular maintenance and defrosting.

Table 7.6 shows the annual financial and electricity savings in the year 2009-10 brought out by partial replacement of the remaining stock.

The analysis here closely follows the methodology adopted for energy efficient lighting measures.

**Table 7.6.** Economic analysis of improved refrigerators

| Region | Net Annual Savings (million US$) | Annual savings per household | Annual electricity savings (TWh) |
|---|---|---|---|
| **5 % GDP growth rate** | | | |
| North | 111.17 | 4.82 | 1.850 |
| South | 113.19 | 5.56 | 1.710 |
| West | 35.75 | 1.94 | 0.530 |
| East | 23.57 | 2.05 | 0.350 |
| North-east | 4.84 | 2.47 | 0.070 |
| All India | 288.53 | | 4.510 |
| **6 % GDP growth rate** | | | |
| North | 111.79 | 5.14 | 1.860 |
| South | 113.13 | 5.89 | 1.710 |
| West | 35.73 | 2.06 | 0.530 |
| East | 24.32 | 2.24 | 0.360 |
| North-east | 4.03 | 2.18 | 0.060 |
| All India | 289.00 | | 4.520 |

The net investments associated with each option amounts to US$ 72.3 million (5% GDP growth rate) and US$ 72.6 million (6% GDP growth rate).

The analysis clearly shows the economic viability for both the options.

**Transport sector**

Table 7.7 gives the fuel savings and cost per kgoe of energy saved for each of the four above options in the year 2009/10. As compared to these figures, the economic cost of energy supply is far higher. In addition to the fuel saving that these options provide, they also have substantial other benefits like release of congestion in urban areas, improvement in the life of engine and reduced demand for spare parts etc.

Of the options mentioned, metro system would generate substantial savings, both in terms of cost and fuel but this option requires substantial initial investment in the order of US$ 11 billion (total for the nine cities considered) during the first 10 years.

Large amount of fuel saving is also possible in the option of modal shift (road to rail).

**Table 7.7.** Annualised cost per unit of energy saved in the transport sector

| | 5% growth rate | | 6% growth rate | |
|---|---|---|---|---|
| | Fuel saving (mtoe) | $/(kgoe saved) | Fuel saving (mtoe) | $/(kgoe saved) |
| Urban buses | | | | |
| North | 1.051 | 0.115 | 1.115 | 0.115 |
| South | 0.919 | 0.115 | 0.964 | 0.115 |
| West | 0.903 | 0.115 | 0.969 | 0.115 |
| East | 0.238 | 0.115 | 0.253 | 0.115 |
| North-East | 0.185 | 0.115 | 0.196 | 0.115 |
| All India | 3.297 | 0.115 | 3.497 | 0.115 |
| Road improvements | | | | |
| North | 2.795 | 0.114 | 3.140 | 0.162 |
| South | 1.677 | 0.121 | 1.852 | 0.173 |
| West | 1.837 | 0.118 | 2.058 | 0.168 |
| East | 1.528 | 0.121 | 1.639 | 0.173 |
| North-East | 0.268 | 0.127 | 0.293 | 0.180 |
| All India | 8.107 | 0.118 | 9.520 | 0.159 |
| Shift from road to rail | | | | |
| North | 4.617 | 0.072 | 5689 | 0.046 |
| South | 2.419 | 0.073 | 2.980 | 0.047 |
| West | 2.837 | 0.075 | 3.496 | 0.048 |
| East | 1.826 | 0.071 | 2.250 | 0.045 |
| North-East | 0.393 | 0.066 | 0.484 | 0.047 |
| All India | 12.091 | 0.072 | 14.899 | 0.047 |
| Metro system | | | | |
| North | 0.811 | -0.108 | 0.811 | -0.108 |
| South | 0.811 | -0.108 | 0.811 | -0.108 |
| West | 0.532 | -0.108 | 0.811 | -0.108 |
| East | 0.566 | -0.101 | 0.566 | -0.101 |
| North-East | 0.000 | 0.000 | 0.000 | 0.000 |
| All India | 2.719 | -0.106 | 2.719 | -0.106 |

Note: - implies overall investment savings over BAU (see text for details)

To sum up, all the above four options are economically justifiable.

**Industrial sector**

Table 7.8 gives the cost per unit of energy saved for the three industries in the year 2009-10. As compared to these estimates, the economic cost of energy supply ranges from 0.2 to 0.33/kgoe thus establishing the economic viability of the energy conservation measures outlined in Chapter 6.

**Table 7.8.** Annualised cost per unit of energy savings in the industrial sector

| Region | Cost (US$/kgoe) | | |
|---|---|---|---|
| | Iron & steel | Chemicals & petro-chemicals | Cement |
| **5 per cent GDP growth rate** | | | |
| North | 0.11 | 0.12 | 0.03 |
| South | 0.11 | 0.12 | 0.03 |
| West | 0.11 | 0.12 | 0.03 |
| East | 0.11 | 0.17* | 0.03 |
| North-East | 0.0 | 0.12 | 0.03 |
| All India | 0.11 | 0.12 | 0.03 |
| **6 per cent GDP growth rate** | | | |
| North | 0.11 | 0.12 | 0.03 |
| South | 0.11 | 0.12 | 0.03 |
| West | 0.11 | 0.12 | 0.03 |
| East | 0.11 | 0.17 | 0.03 |
| North-East | 0.0 | 0.12 | 0.03 |
| All India | 0.11 | 0.12 | 0.03 |

* In the Eastern region petrochemical industry is entirely naphtha based which has higher energy consumption compared to natural gas based plants.

The incremental annualised investment for the three industrial sub-sectors put together was worked out to be US$ 1751.22 and 1766.45 for the 5 per cent and 6 per cent rates of growth of GDP scenarios.

**Agricultural sector**

Table 7.9 shows the costs incurred per unit of energy saved for measures in the agricultural sector. As can be seen retrofitting of pumps is an extremely viable option. The total costs per energy saved of all measures (retrofitting of

pumps and penetration of drip and sprinkler systems) is far higher than the cost of supplying energy. This is because the drip system has high capital intensity and is essentially a water conserving option. This option is considered largely due to growing concerns regarding the sustainability of tapping groundwater for irrigation purposes.

**Table 7.9.** Annualized cost per unit of energy saved in the Agriculture sector ($/kgoe)

| | I | II |
|---|---|---|
| North | 0.030 | 0.47 |
| West | 0.030 | 0.24 |
| South | 0.032 | 0.54 |
| East | 0.027 | 0.10 |
| All India | 0.030 | 0.39 |

I - Retrofitting of pumps
II - Retrofitting of pumps and penetration of drip and sprinkler systems

7.4.1.2 Alternative strategy II

**Domestic sector**

Solar cookers: In this case, the option of a portion of urban residential cooking energy demand to be met by solar cookers was analysed.

The output of the economic analysis of solar cookers for meeting a part of domestic cooking energy demand is presented in Table 7.10, which gives the cost per unit of LPG saved.

As against specific costs tabulated above the economic cost of LPG was worked out to be about US$ 0.48/kg - US$ 0.6/kg thus making solar cookers a viable option in some regions of the country.

The annualised incremental investments of this option are worked to be US$ 105 million and US$ 100 million in case of the two scenarios of 5 per cent and 6 per cent GDP growth rate.

**Table 7.10.** Cost per unit of LPG saved through the use of solar cookers

| Region | Cost of solar cooker (US$/Kg of LPG saved) |
|---|---|
| **5 % GDP growth rate** | |
| North | 0.47 |
| South | 0.41 |
| West | 0.50 |
| East | 0.46 |
| North-east | 0.62 |
| All India | 0.46 |
| **6 % GDP growth rate** | |
| North | 0.44 |
| South | 0.39 |
| West | 0.47 |
| East | 0.44 |
| North-east | 0.58 |
| All India | 0.43 |

<u>Biogas plants and improved cookstoves</u>: The economic analysis of biogas to meet domestic energy demand in rural areas was carried out by taking the annualised cost of the stock of biogas plants and improved cookstoves in the year 2010 and the associated savings in firewood. The results of the analysis presented in Table 7.11 below give the annualised cost per unit of firewood saved. These costs which average at US$ 0.016/kg of firewood at the national level are much lower than the economic cost of supply of fuelwood.

**Table 7.11.** Economic analysis of Biogas plants

| | Annualised Cost (US$/Kg of firewood saved) | Annual firewood savings (Mt) |
|---|---|---|
| North | 0.0169 | 3.27 |
| South | 0.0148 | 4.24 |
| West | 0.0188 | 5.89 |
| East | 0.0129 | 2.44 |
| North-East | 0.0045 | 0.62 |
| All India | 0.0160 | 16.46 |

The additional annualised costs of investing in this option are worked to be about US$ 375.4 million by the year 2010.

**Transport sector**

CNG

Table 7.12 shows the total fuel savings and cost per kgoe of fuel saved. The cost per unit of fuel saved ($ /kgoe) ranges from 0.064 to 0.071 which is far below the economic cost of supply.

**Table 7.12.** Fuel savings and cost per unit of fuel saved.

| | Total savings (mtoe) | Cost per 2009-10 ($/kgoe saved) |
|---|---|---|
| North | 1.71 | 0.065 |
| West | 0.92 | 0.064 |
| South | 0.25 | 0.068 |
| East | 0.25 | 0.068 |
| North-east | 0.12 | 0.071 |
| All India | 3.24 | 0.068 |

Table 7.13 gives the annualised incremental costs over BAU for alternative strategies for the year 2010.

**Table 7.13.** Annualised incremental requirements for alternative strategies (million US$)

| | Domestic sector | | Industrial sector | | Transport sector | | Agricultural sector[1] | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5% | 6% | 5% | 6% | 5% | 6% | 5% | 6% | 5% | 6% |
| Alternative strategy I | | | | | | | | | | |
| North | 9 16 | 9.17 | 42 41 | 49 57 | 684 1 | 813 8 | 1091.1 | 1524.5 | 1826 77 | 2397 04 |
| West | -10 01[2] | -8.63[2] | 359.15 | 371 58 | 475 8 | 567 1 | 269 8 | 377.0 | 1094 74 | 1307 05 |
| South | 1 41 | 1 52 | 531 27 | 527.76 | 399 1 | 483 5 | 469 0 | 655.3 | 1400 78 | 1668 08 |
| East | 0 60 | 0 66 | 814 59 | 814.59 | 283 3 | 357 6 | 58 9 | 82 4 | 1157 39 | 1255 25 |
| North-East | -0 03 | -0.02 | 5 35 | 4 49 | 81 1 | 95 7 | - | - | 86 42 | 100.21 |
| All India | 1 14 | 2 70 | 1752.77 | 1767 99 | 1923 4 | 231 7 | 1888 8 | 2639 2 | 5566 10 | 6727.63 |
| Alternative strategy II | | | | | | | | | | |
| North | 31 77 | 30 37 | - | - | 111.72 | 111 72 | - | - | 142.94 | 141 54 |
| West | 25 78 | 24 65 | - | - | 58 76 | 58 76 | - | - | 84.43 | 83 30 |
| South | 28 80 | 27.56 | - | - | 16 63 | 16 63 | - | - | 45.34 | 44.10 |
| East | 15.96 | 15.25 | - | - | 16.63 | 16 63 | - | - | 32 50 | 31 79 |
| North-East | 2.61 | 2.50 | - | - | 8.78 | 8.78 | - | - | 11.30 | 11 19 |
| All India | 104.92 | 100.33 | - | - | 212.53 | 212.53 | - | - | 316.50 | 311.91 |

[1] Cost figures include drip and sprinkler irrigation systems (essentially water conserving measures) comprising 95% of the costs and retrofitting pumps which comprise the remaining 5% of the costs

[2] Net incremental investment savings.

7.4.1.3 Combination strategy: In this strategy, where both energy conservation measures (as in Alternative Strategy I) and use of alternative energy sources (as in Alternative Strategy II) are considered, the costs incurred on the demand side are obtained simply by summing up the costs given in Table 7.13.

7.4.2 Supply side

In alternative strategy I, where washing of non-coking coals for use in TPS units, and T&D loss reduction are the major measures to enhance the efficiency of the energy supply industry, the total economic costs are estimated at $101.9 billion in the low GDP growth case, and $116.6 billion in the high GDP growth case. These costs imply a reduction by 20.7% and 19.9% from the corresponding BAU levels. This substantial reduction is due also to the fact that energy conservation measures are affected on the demand side -- which in turn reduces the need to invest in energy supply projects.

**Table 7.14.** Changes in economic costs of energy supply in the alternative strategies (5% per annum GDP growth case)

| | Alternative strategy I | Alternative strategy II | Combination strategy |
|---|---|---|---|
| **Percent reduction from BAU strategy** | | | |
| Total | 20.7 | -0.8 | 19.9 |
| Hydrocarbon field development | 0.05 | -0.01 | 0.05 |
| Natural gas pipelines | | | |
| - on land | 0.2 | -11.0 | -10.8 |
| - offshore | 0.15 | -8.2 | -8.1 |
| Power supply | 20.3 | -3.6 | 16.7 |
| Power shortages | -95.7 | 20.6 | -82.1 |
| Net fuel imports | 74.8 | 3.9 | 75.4 |
| - Coal | 366.6 | 0 | 366.6 |
| - Crude oil | 0 | 0 | 0 |
| - Refined products | 77.5 | 7.9 | 78.8 |
| **Memo item** | | | |
| Total costs ($ million) | 101859 | 129418 | 102856 |
| Coal washing | | | |
| Costs ($ million) | 36.8 | 0 | 36.8 |

In alternative strategy II, where the only supply side changes are for enhancing RET based power generating capacity (windfarms and small hydro units), the costs for supplying

energy actually increase from BAU levels. In the low growth case, total costs are estimated at $129.4 billion (an increase of 0.8% from the BAU level), and in the high growth case at $146.5 billion (an increase of 0.7% from the BAU level). It may be noted that the increase in cost essentially reflects increase in RET based power generating capacity, without any reduction in expansion of conventional, despatchable power generating stations. This only leads to a marginal reduction in peak power and electrical energy shortages.

**Table 7.15.** Changes in economic costs of energy supply in the alternative strategies (6% per annum GDP growth case)

| | Alternative strategy I | Alternative strategy II | Combination strategy |
|---|---|---|---|
| **Percent reduction from BAU strategy** | | | |
| Total | 19.9 | -0.7 | 19.2 |
| Hydrocarbon field development | 0.03 | -0.01 | 0.03 |
| Natural gas pipelines | | | |
| - on land | 7.2 | -9.6 | -2.4 |
| - offshore | 5.5 | -7.3 | -1.8 |
| Power supply | 18.6 | -3.2 | 15.4 |
| Power shortages | 48.2 | 35.9 | 84.1 |
| Net fuel imports | 53.6 | 2.8 | 56.4 |
| - Coal | 70.4 | 0 | 70.4 |
| - Crude oil | 0 | 0 | 0 |
| - Refined products | 65.1 | 6.6 | 71.7 |
| **Memo item** | | | |
| Total costs ($ million) | 116558 | 146541 | 117560 |
| Coal washing | | | |
| Costs ($ million) | 49.8 | 0 | 49.8 |

In the combination strategy, where both efficiency enhancement measures and alternative energy supply options are considered simultaneously, the total costs reduce substantially from BAU levels -- by 19.2% in the low growth case and 19.9% in the high growth case.

Similar changes in costs across strategies are also evident at the regional level (see Appendices 7.1 and 7.2 for the low and high growth cases respectively). As for the BAU strategy, the largest share of costs are incurred in the Western Region, and the least in the Northeastern region.

Although coal and lignite production and their costs, as well as hydrocarbon exploration levels, remain the same across various strategies for a particular GDP growth rate, oil/gas field development and gas pipeline costs change marginally (see Tables 7.14 and 7.15). This reflects the difference in free gas production levels (in line with total gas demand) between the various strategies.

Differences across strategies are substantial for power supply costs. They reduce in strategy I from BAU levels (as smaller capacity additions are required), and increase in strategy II (as more RET capacity is added). In the combination strategy also, power supply costs reduce, although not as much as in strategy I. The percentage changes from BAU levels are given in Tables 7.14 and 7.15 for the low and high growth cases respectively. They are reflected in changes in the unit cost of sales across various strategies, and in each region, as shown in Appendix 7.3. Costs of installing and using non-coking coal washeries are also shown in these tables; it is clear that they account for less than 0.05% of total costs in all strategies.

Perhaps the greatest differences are observed with regard to net fuel import bills. In strategy I, the reduction of foreign exchange requirements for fuel imports are substantial -- by about 75% from the BAU level in the low growth case, and by nearly 54% in the high growth case. The net fuel import bill reduces to $5.9 billion in the low growth case, and $15 billion in the high growth case. Fuel import bills in strategy II also reduce somewhat from BAU levels, but the change is only marginal. The relative effects on the net fuel import bills clearly indicates the need to implement conservation measures both on energy supply and demand sides. Tables 7.14 and 7.15 also show that net fuel import bills further reduce in the combination strategy, but fall only marginally below those in strategy I.

## 7.5 Valuing environmental impacts/damage from energy production and use

Indirect techniques were employed involving the use of two approaches - preventive expenditures and change in productivity to value environmental impacts from energy production and use. Paucity of data on environmental impacts both at a site specific level as well as over regions as wide as those defined in this study made it difficult to place a monetary value on such impacts. Thus, this exercise has been

limited to valuing the environmental impacts of air pollution, namely total suspended particulates (TSPs) and oxides of nitrogen (NOx), and forest lost due to submergence from hydroprojects and coal mining.

7.5.1 Discount rates used

The social discount rate for this part of the study was calculated using the standard formula for discounting future consumption:

S = Ce + p where

C = rate of growth of per capita real consumption

e = elasticity of marginal utility of consumption

p = rate of pure time preference

An assumption is made of constant elasticity of the marginal utility of consumption to be 2 which is commonly found in empirical work. We take the position that on ethical grounds (i.e. equality across generations) there can be no discounting of utility over time periods, so time preference rate is zero. Rate of growth of per capita real private consumption over the period 1980-81 to 1989-90 was 2.7% (CMIE, 1991). Taking the past growth rate as a guide, C is set at 2.7% and accordingly, S works out at 5.4%. This is rounded of to 5% as the margin of error so introduced would be negligible.

A sensitivity analysis using discount rates of 3%, 5%, 7%, 10% and 12% is carried out to assess the implications of different discount rates on the costs estimated.

7.5.2 Air quality

The indicators of air quality that are valued here are total suspended particulates (TSPs), oxides of nitrogen ($NO_x$) and sulphur dioxide ($SO_2$). Environmental damage due to each pollutant from power plants is estimated by region and pollution control costs are used as a proxy for damage avoidance cost or a damage abatement approach, to obtain a lower bound value for damages (Shulz and Shulz, 1991). The expenditure which is accepted (or not accepted) for environmental protection (e.g. electrostatic precipitators (ESPs) for control of TSPs) is taken as an indication of what society is willing to pay for a reduction in pollution. Thus if these devices are actually installed, one can assume that willingness to pay is greater than or at least equal to the cost of abatement. The study should have attempted to obtain an independent estimate of willingness to pay since these would enable us to address the question whether society should pay for abatement. This exercise is however, much

more complicated and beyond the scope of this study and so an assumption is made that the willingness to accept (or not accept) abatement costs is an indication of the willingness to pay to avoid pollution. For example, the cost per unit pollutant removed is the amount society is willing to pay to avoid the damage caused by that unit pollutant. The resulting improvement is worth at least that much to society.

Estimating the cost per unit pollutant removed involves the following stages (Baasel, 1985):

(1) Calculation of (pollutant) emissions per unit production with no controls in place.

(2) Estimation of pollutant emissions per unit production using control equipment, e.g. electrostatic precipitators used to control TSP emissions from power plants.

(3) Estimation of pollutant reduction per unit production.

(4) Calculating the levelized annual control costs per unit production and costs per unit pollutant removed. This latter value is used to place a lower bound on environmental damage (except perhaps relating to sulphur dioxide emission control) caused by these pollutants and is the figure used to value estimated emissions of the particular pollutant in each energy region from power plants projected to come up between 1990 and 2010.

### 7.5.3 Business-as-usual strategy

7.5.3.1 Particulate emission: Table 7.16 provide a summary of the minimum cost of environmental damage from TSP emissions from power plants by energy region for a 5% and 6% GDP growth rate at various discount rates. The cost per unit of TSP removed ranges between 0.18 cents/kg at a 3% discount rate, 0.22 cents/kg at a 5% discount rate to about 0.37 cents/kg at a 12% discount rate. The pollution (TSP) cost per unit of electricity generated ranges between 0.038 cents/kWh at 3% discount rate, 0.046 cents/kWh at a 5% discount rate and 0.078 cents/kWh at a 12% discount rate. This implies that if no ESPs were installed, the total economic costs of generating electricity would have to be increased by at least these amounts to reflect pollutant costs, if a total cost approach is to be adopted*.

* Economic LRMC of generating electricity ranges between 1.01 to 4.06 cents/kWh (see TERI, 1991).

**Table 7.16.** Total environmental damage from TSPs from coal based thermal power plants for the period 1990-2010*

('000$, 1990/91 prices)

| Region | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| **5% GDP growth rate** | | | | | |
| North | 84.68 | 101.41 | 119.94 | 150.33 | 171.87 |
| West | 78.81 | 94.39 | 111.63 | 139.92 | 159.96 |
| South | 70.35 | 84.24 | 99.63 | 124.88 | 142.78 |
| East | 79.92 | 95.71 | 113.19 | 141.88 | 162.20 |
| North-east | n.a. | n.a. | n.a. | n.a. | n.a. |
| All India | 313.76 | 375.75 | 444.38 | 557.01 | 636.82 |
| **6% GDP growth rate** | | | | | |
| North | 99.58 | 119.25 | 141.03 | 176.78 | 202.10 |
| West | 90.67 | 108.58 | 128.41 | 160.96 | 184.02 |
| South | 83.55 | 100.05 | 118.33 | 148.32 | 169.57 |
| East | 93.32 | 111.76 | 132.17 | 165.67 | 189.40 |
| North-East | n.a. | n.a. | n.a. | n.a. | n.a. |
| All India | 367.11 | 439.65 | 519.95 | 651.73 | 745.11 |

* The assumptions made to arrive at these values are:
(i) The costs of ESPs vary between \$ 3.9-5 million for a 210 MW plant and between \$ 8.4-11.1 million for a 500 MW plant, depending on the efficiency of removal required. Assuming a removal efficiency of 99.8%, the per unit cost of the ESP has been computed using the upper values as an average of the 210 and 500 MW plants i.e. (5+11.1)/710 million \$/MW. [Source: Unpublished data, M. Kirorimal, Manager Commercial, ESP projects, BHEL]
(ii) Life of an ESP is assumed to be 30 years and O&M costs to be 2% of total capital costs.
(iii)The conversion of capacity to generation has been carried out on the assumption of an all India average plant utilization of 4900 hours of generation.
(iv) It is assumed that 0.65 kg coal is consumed per kWh electricity generation.
(v) Estimation of uncontrolled emissions of TSPs are based on the work of T.T. Shen (1980) where it is estimated that TSP emissions are 0.8 times the weight of ash in coal (which is 40% for Indian coals used in power plants).

7.5.3.2 <u>$NO_x$ emissions</u>: An identical exercise (as for TSPs) is carried out for $NO_x$ emissions in the country. Table 7.17 provide a summary of the lower bound of the cost of environmental damage (as measured by its control cost) from $NO_x$ emissions from thermal power plants by energy region for a 5% and 6% GDP growth rate at various discount rates using selective catalytic reduction (SCR) techniques. The cost per

unit $NO_x$ removed ranges from $ 1.18/kg at a 3% discount rate to $ 1.20/kg at 5% and $ 1.30/kg at a 12% discount rate. The pollution ($NO_x$) cost per unit electricity generated ranges between 0.69 cents/kWh at a 3% discount rate and 0.76 cents/kWh at a 12% discount rate. This implies that were there no SCRs installed, the total economic costs of generating electricity would have to be increased by the same amount to reflect pollution costs, if a total cost approach is adopted. The levelized annual costs of $NO_x$ control range from 0.59 cents/kWh at 3% discount to 0.60 cents/kWh at 5% and 0.65 cents/kwh at 12% discount rate.

**Table 7.17.** Total environmental damage from $NO_x$ from coal based Thermal power plant (1990-2010)*

('000$, 1990/91 prices)

| Region | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| **5% GDP growth rate** | | | | | |
| North | 109.94 | 112.3 | 114.91 | 119.19 | 122.22 |
| West | 103.61 | 105.80 | 108.23 | 112.21 | 115.04 |
| South | 91.71 | 93.67 | 95.84 | 99.39 | 101.91 |
| East | 106.61 | 108.83 | 111.29 | 115.33 | 118.19 |
| North-east | n.a. | n.a. | n.a. | n.a. | n.a. |
| All India | 411.87 | 420.6 | 430.26 | 446.12 | 457.36 |
| **6% GDP growth rate** | | | | | |
| North | 130.32 | 133.13 | 136.23 | 141.33 | 144.94 |
| West | 120.12 | 122.68 | 125.51 | 130.15 | 133.44 |
| South | 109.69 | 112.04 | 114.65 | 118.92 | 121.95 |
| East | 125.15 | 127.79 | 130.70 | 135.48 | 138.87 |
| North-East | n.a. | n.a. | n.a. | n.a. | n.a. |
| All India | 485.29 | 495.64 | 507.09 | 525.88 | 539.20 |

The assumptions made to arrive at these vales are:

(1) Capital costs of SCR assumed at $36.425/MW installed capacity and O&M costs at $ 0.054/kWh generated.
(2) Life of an SCR assumed to be 30 years.
(3) Removal efficiency assumed to be 85%.
(4) Estimation of uncontrolled emissiions are based on the work of T.T. Shen (1980).

7.5.3.3 Sulphur oxide emissions: An exercise was also carried out to examine the merits of installing flue gas desulphurizers (FGDs) in the Indian context. As the sulphur content of most Indian coals generally varies between 0.3-0.5%, FGD scrubbers are of limited use. However, certain regions in India have coals with a high sulphur content, for example, Assam coal has a sulphur content of 3%. In the future, FGD techniques may find limited application either in the Singrauli region (should capacity expansion occur at the pace planned) or in

metropolisis like Delhi where the environment is already stressed.

The levelized annual cost of FGD and the cost per unit $SO_2$ removed are given in Tables 7.18 and 7.19 respectively.

**Table 7.18.** Cost per unit pollutant ($SO_x$) removed ($/kg, 1990/91 prices)

| Sulphur content in coal (%) | Discount rates 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| 0.5 | 3.54 | 3.62 | 3.71 | 3.86 | 3.97 |
| 1.0 | 1.77 | 1.81 | 1.86 | 1.93 | 1.98 |
| 2.0 | 0.88 | 0.90 | 0.93 | 0.97 | 0.99 |
| 3.0 | 0.59 | 0.60 | 0.62 | 0.64 | 0.66 |
| 4.0 | 0.44 | 0.45 | 0.46 | 0.48 | 0.50 |
| 5.0 | 0.35 | 0.36 | 0.37 | 0.38 | 0.40 |

**Table 1.19.** Levelized annual cost (cents/kWh, 1990/91 prices)

| PLF (%) | Discount rates 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| 61 | 1.97 | 2.01 | 2.06 | 2.15 | 2.21 |
| 65 | 1.96 | 2.00 | 2.05 | 2.13 | 2.18 |
| 68 | 1.95 | 1.99 | 2.04 | 2.11 | 2.16 |
| 70 | 1.95 | 1.99 | 2.03 | 2.10 | 2.15 |
| 75 | 1.94 | 1.97 | 2.01 | 2.08 | 2.13 |

(i) The costs mentioned in EPRI (1988) of $175/kW installed capacity and 18 mills/kWh O&M cost would be applicable to the Indian Situation.
(ii) 4900 hours of generation.
(iii) Coal consumption = 0.65 kg coal/kWh electricity generated.
(iv) 90% removal efficiency of wet scrubbing process.
(v) Uncontrolled emissions of sulphur dioxide were estimated at 19 times sulphur content of coal (T.T.Shen, 1980).
(vi) 0.5% sulphur content in coal (average Indian coal).
(vii) Life of an FGD assumed to be 30 years.

Sensitivity analysis on the sulphur content in coal revealed as expected, that the larger the content of sulphur in coal, the lower becomes the costs of removing it. This explains why it is not economical to install FGDs for low sulphur Indian coal, except perhaps for Assam coal and is an indication that the reduction of $SO_2$ emissions using FGDs is not worth the cost of installing such preventive equipment. In very stressed environments, however, such as that of Delhi and Singrauli, it could well be that the cumulative damage

potential of even low emissions of $SO_2$ could be perceived as worth incurring the expenditure. All equipment costs are subject to an annual average real price inflation of 1.5%. This has been carried out for all equipment except FGDs since the calculations do not involve a time frame for installation. Hence even in terms of an avoidance cost, these figures indicate a lower bound.

7.5.4 Aternative strategy I

This strategy allows for efficiency improvements in the power sector in terms of coal washing and T&D loss reduction. These two measures contribute to reduced air pollution.

7.5.4.1 Particulate emission: Table 7.20 provides a summary of the minimum cost of environmental damage from TSP emissions from power plants by energy region for a 5% and 6% GDP growth rate at various discount rates. The cost per unit TSP removed ranges from 0.235 cents/kg at a 3% discount rate, to about 0.282 cents/kg at a 5% discount rate to about 0.478 cents/kg at a 12% discount rate. The TSP pollution cost per unit of electricity generated ranges between 0.036 cents/kwh at a 3% discount rate 0.043 cents/kwh at a 5% discount and 0.073 cents/kwh at a 12% discount rate.

**Table 7.20.** Total environmental damage from TSPs from coal based thermal power plants for the period 1990-2010

('000 $) (1990/91)

| Region | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| **5% GDP growth rate** | | | | | |
| North | 38.93 | 46.62 | 55.13 | 69.11 | 79.01 |
| West | 67.99 | 81.43 | 96.30 | 120.71 | 138.00 |
| South | 60.0 | 71.86 | 84.98 | 106.52 | 121.78 |
| East | 58.60 | 70.18 | 83.00 | 104.04 | 118.95 |
| North East | n.a. | n.a. | n.a. | n.a. | n.a. |
| All India | 225.53 | 270.09 | 319.42 | 400.37 | 457.74 |
| **6% GDP growth rate** | | | | | |
| North | 58.09 | 69.57 | 82.27 | 103.12 | 117.9 |
| West | 94.54 | 113.21 | 133.89 | 167.83 | 191.87 |
| South | 84.46 | 101.14 | 119.62 | 149.94 | 171.42 |
| East | 54.22 | 64.93 | 76.79 | 96.25 | 110.04 |
| North East | n.a. | n.a. | n.a. | n.a. | n.a. |
| All India | 291.3 | 348.86 | 412.57 | 517.14 | 591.23 |

The assumptions made to arrive at these costs are the same as those for the BAU strategy, except that power plants running on washed coal use 0.44 kg of coal per kWh generated and operate for 5330 hours per year.

7.5.4.2 Nitrogen oxide emissions: Table 7.21 provides a summary of the lower bound of the cost of environmental damage (as measured by its control cost) from NOx emissions from thermal power plants by energy region for a 5% & 6% GDP growth rate at various discount rates using SCR. The cost per unit NOx removed ranges from $1.45/kg at a 3% discount rate to $1.48/kg at a 5% discount rate and $1.59/kg at 12% discount rate. The $NO_x$ cost per unit electricity generated ranges between 0.68 cents/kwh at a 3% discount rate and 0.75 cents/kwh at a 12% discount rate. The levelized annual costs of NOx control range from 0.583 cents/kwh at 3% discount to 0.595 cents/kwh at 5% and 0.644 cents/kwh at 12% discount rate respectively.

**Table 7.21.** Total environmental damage from NOx from coal based thermal power plants (1990-2010)

($ million) (1990/91 prices)

| Region | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| **A. 5% GDP Growth Rate** | | | | | |
| North | 55.37 | 56.47 | 57.69 | 59.68 | 61.10 |
| West | 94.00 | 95.92 | 98.03 | 101.57 | 103.97 |
| South | 80.18 | 81.86 | 83.72 | 86.77 | 88.93 |
| East | 77.67 | 79.30 | 81.11 | 84.07 | 86.17 |
| North East | n.a. | n.a. | n.a. | n.a. | n.a. |
| All India | 307.22 | 313.54 | 320.54 | 332.03 | 340.16 |
| **B. 6% GDP Growth Rate** | | | | | |
| North | 82.64 | 84.27 | 86.07 | 89.03 | 91.12 |
| West | 131.26 | 133.91 | 136.83 | 141.64 | 145.04 |
| South | 114.18 | 116.54 | 119.14 | 123.42 | 126.44 |
| East | 72.79 | 74.3 | 76.0 | 78.71 | 80.65 |
| North East | n.a. | n.a. | n.a. | n.a. | n.a. |
| All India | 400.88 | 409.01 | 418.01 | 432.78 | 443.25 |

Once again the assumptions of the BAU strategy hold for this analysis.

7.5.4.3 Sulphur oxide emissions: Since FGDs are not currently a planned option, one does not know the time frame in which it will be installed. Further, while washing will reduce sulphur content of coal, it has not been estimated for the study. Hence there is no change in the cost estimates of SOx emissions from the BAU strategy.

7.5.5 Alternative strategy II

This is the strategy where renewable energy technologies will find wide application; the thermal capacity expansion remaining the same as under the 5% and 6% GDP growth rates of the BAU strategy. Hence, all cost estimates arrived for the BAU strategy will hold for this strategy as well.

7.5.6 Combination strategy

This allows for efficiency improvements of Strategy I and RET capacity additions of Strategy II. The expansion of thermal power systems -- and hence environment related costs -- arrived at for Strategy I hold true for this strategy as well.

7.5.7 Value of forests lost due to hydropower and coal projects

As seen earlier in the study, hydropower and coal mining projects have had a considerable impact on forest area, either due to submergence (for hydroprojects) or deforestation (for coal and lignite mining activity). As damage is clearly established, damages are valued at economic prices. To assess the value of forest area lost due to hydro and coal projects, the following are identified for each energy region: (i) the extent of forest land affected, and (ii) the type of forest involved. The value of forest lost by type (per hectare) is then assessed in terms of its goods and services. The value of the forest land lost is then assumed to be the present worth of goods and services foregone by society on account of energy projects* at the various discount rates referred to earlier.

The value of a unit area of forest is estimated for each forest type based on both economic goods and environmental services provided by a forest . The value of environmental services (such as production of oxygen, conversion to animal protein, soil conservation and maintenance of soil fertility, recycling of water and humidity control, sheltering of birds, and control of air pollution etc.) are taken from Das (1980) in the absence of any other information. Surrogate market techniques are used to value such benefits from a medium

---

* It could well be that some hydro and coal project do include timber costs in their economic appraisal. It is not clear, however, which projects do so. In the absence of information we assume here that forest loss in terms of timber are not included in the appraisal. Environmental services of forests are however, not included in any such appraisals.

sized tree which has a biomass yield of 50 tons over a period of 50 years*. On the basis of these estimates, the value of environmental services provided by one tonne of biomass is about $59 at current prices. An average organic productivity level per hectare is used for four types of forests - tropical, subtropical, temperate and alpine, as a basis for the calculations shown in Appendix 7.1. The economic goods considered are timber and industrial wood, fuelwood, minor forest produce, grazing and recreation. Stump values are estimated for timber, industrial wood and fuelwood. The present worth of a forest is then estimated as the sum of the annual streams of economic goods and environmental services. This is summarized at various discount rates in Tables 11 through 13 below.

Economic losses of forest submergence are given in Table 7.22, and for deforestation from coal and lignite mining projects in Tables 7.23 and 7.24. Table 7.25 provides an average estimate of the forest lost per tonne of coal for the various energy regions.

**Table 7.22.** Value of forest area lost due to hydroprojects

(1990-91 prices) (million $)

| Region | Forest affected | Capacity (MW) | 12% | 10% | 7% | 5% | 3% |
|---|---|---|---|---|---|---|---|
| North | 9452 66 | 9124 50 | 67 14 | 80.16 | 111 57 | 147 59 | 208.01 |
| South | 3114 50 | 1500 00 | 44 62 | 53 27 | 74 15 | 98.09 | 138.24 |
| East | 1711 00 | 1360 00 | 5 39 | 18.55 | 25 82 | 34 15 | 48.13 |
| West | 69899 00 | 4168 00 | 1001 41 | 1195 6 | 1664 2 | 2201 43 | 3102 59 |
| N-East | 18 50 | 1260 00 | 0 07 | 0 09 | 0 12 | 0.16 | 0 22 |
| Total | 84195 66 | 17412 50 | 1118.63 | 1347 67 | 1875 86 | 2481 42 | 3497 19 |

* Time and resources did not permit us to a separate valuation of environmental services provided by forests on evsen to improve on these figures.

**Table 7.23.** Value of forest area affected by coal mining projects

(1990-2010) (million $)

| Region | Forest area (ha) | Forest type | Coal production ($10^6$ tons) | Discount Rates 12% | 10% | 7% | 5% | 3% |
|---|---|---|---|---|---|---|---|---|
| East | 34661 | TDD | 245 27 | 186 34 | 222 48 | 309 67 | 409 64 | 577 35 |
| West | 10999 | TDD+TMD | 48 01 | 108 36 | 129 37 | 180 07 | 238 20 | 335 72 |
| South | 12885 | TMD | 17 36 | 184 60 | 220 40 | 306 78 | 405 82 | 571 96 |
| North-East | 225 | TWE | 2 3 | 2 66 | 3 18 | 4 43 | 5 86 | 8 25 |
| All India(Total) | 58770 | | 312 94 | 481 97 | 575 42 | 800 95 | 1059 52 | 1493 27 |

TDD Tropical Dry Deciduous

TMD Tropical Moist Deciduous

TWE Tropical Wet Evergreen

**Table 7.24.** Value of forest area affected by lignite mining projects

(1990-2010) (million $, 1990 prices)

| Region | Forest area (ha) | Forest Type | Lignite Prod (million t) | Discount Rates 12% | 10% | 7% | 5% | 3% |
|---|---|---|---|---|---|---|---|---|
| West | 179 | TDD+TMD | 0 78 | 1 76 | 2 1 | 2 92 | 3 86 | 5 45 |
| South | 13279 | TMD | 17 89 | 190 25 | 227 15 | 316 17 | 418 24 | 589 46 |
| All India | 13458 | | 18 67 | 192 01 | 229 25 | 319 09 | 422 1 | 594 91 |

Note In the Northern Region, lignite is mined in the State of Rajasthan which does not have any area under forests Hence, this exercise was not undertaken

**Table 7.25.** Average value of forest loss per tonne of coal produced

| | Discount rates 12% | 10% | 7% | 5% | 3% |
|---|---|---|---|---|---|
| $/tonne of coal produced | 1.54 | 1.84 | 2.56 | 3.39 | 4.77 |

7.5.8 Value of land affected by developing of overburden from coal mining projects

An attempt was made to value the land affected by the overburden generated by coal and lignite mining projects. The additional production from open cast mining is taken as the basis for this calculation, with a stripping ratio of 3

$m^3/t$, to obtain the total overburden created by coal mining*. Of the total life time (35 years) overburden, 10% is assumed to be external overburden. This overburden would be dumped on land outside the quarry area which has to be levelled, contoured and renourished after a period of time. Total area required for external dumps from opencast coal projects is estimated and land reclamation costs per hectare are calculated using normative costs per tonne of coal as estimated by the Planning Commission (1988). Land reclamation costs per hectare calculated are $ 9190. The same norm is used to estimate the value of land affected by the overburden by lignite projects. Tables 7.26 and 7.27 summarize the area and the costs of reclamation involved in coal and lignite projects being developed in the period 1990-2010.

**Table 7.26.** Value of land affected by external overburden from coal mining projects

(1990/91 prices)

| Region | External dump area reqd. (ha) | Reclamation cost (million $) |
|---|---|---|
| East | 4865 | 44.7 |
| West | 1746 | 16.0 |
| South | 489 | 4.5 |
| North-East | 69 | 0.6 |
| All India (Totals) | 7169 | 65.9 |

**Table 7.27.** Value of land affected by external overburden from lignite projects

(1990-91 prices)

| Region | External dump area reqd. (ha) | Reclamation cost (million $) |
|---|---|---|
| West | 23.37 | 0.2 |
| South | 536.67 | 4.9 |
| North | 65.4 | 0.6 |
| All India | 625.42 | 5.7 |

Note : All lignite production is from open cast projects.

---

* It is assumed for this exercise that any overburden from existing mining projects is being used for refilling the open pits. Dumping considered here is for new projects only.

Thus, at a minimum, the value of land affected by the dumping of overburden from opencast coal and lignite mining over the period 1990/91 to 2009/10 is estimated at $65.9 million and $ 5.7 million, respectively using reclamation costs as a minimum value placed on getting land back to its original condition.

## 7.6 Total economic costs

Table 7.28 gives the total economic costs associated with various development strategies. These include direct economic costs related to demand and supply side investments and operations, as well as environmental costs.

**Table 7.28.** Total economic costs incurred in various development strategies ($ million, 1990-91 prices)

| | 5% GDP Growth Rate | 6% GDP Growth Rate |
|---|---|---|
| BAU | 130,743 | 147,942 |
| Alternative strategy I | 109,630 | 125,594 |
| Alternative strategy II | 130,228 | 147,428 |
| Combination strategy | 109,115 | 125,079 |

It may be noted from Table 7.28 that in both the low and high GDP growth cases, the combination strategy entails the lowest cost, followed closely by alternative strategy I, and the BAU strategy entails the maximum costs.

## 7.7 Monetary estimates of environmental impacts of energy production and use for Singrauli and Delhi

Certain regions/cities are expected to come under severe environmental stress in future, if activities expand to the year 2010 as planned. In chapter IV, location specific environmental impacts for Singrauli and Delhi are given. In this section, we try to place a monetary value on these impacts following the same approach as that used for the rest of the country.

### 7.7.1 Singrauli region

7.7.1.1 BAU strategy: The impacts valued in the Singrauli region

in the year 2010 assuming a power generating capacity of 18,000 MW are from total suspended particulates, oxides of nitrogen and sulphur dioxide, forest lost due to coal mining projects and land affected by external overburden dumps. The estimates are summarized in Table 7.29 through 7.32 below.

Total land estimated to be affected by external overburden dumps from coal mining projects is 732 ha. Total reclamation expenditure estimated is $6.72 million.

**Table 7.29.** Relating to TSP emissions from power plants (1990-91 prices)

| | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| 1. Levelized annual costs (cents/kWh) | 0.037 | 0.045 | 0.053 | 0.066 | 0.075 |
| 2. Cost/unit TSP removed (cents/kg) | 0.018 | 0.021 | 0.025 | 0.031 | 0.037 |
| 3. Total environmental damage ('000 $) (1990-2010) | 8.0 | 9.5 | 11 | 14 | 16 |

**Table 7.30.** Relating to SOx emissions from power plants (1990-91 prices)

| | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| 1. Levelized annual costs (units/kWh) | 0.26 | 0.27 | 0.27 | 0.28 | 0.29 |
| 2. Cost/unit SOx removed (cents/kg) | 44.67 | 46.66 | 47.76 | 49.57 | 50.85 |
| 3. Total environmental damage (million $) (2010) | 31 | 31 | 32 | 33 | 34 |

**Table 7.31.** Relating to NOx emissions from power plants (1990-91 prices)

| | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| 1. Levelized annual costs (units/kWh) | 0.076 | 0.077 | 0.078 | 0.080 | 0.082 |
| 2. Cost/unit NOx removed (cents/kg) | 14.93 | 15.15 | 15.40 | 15.81 | 16.09 |
| 7 3. Total Environmental damage (million $) (2010) | 14 | 15 | 15 | 15 | 15 |

**Table 7.32.** Value of forest area affected by coal mining projects

| Forest area acquired (ha) | Forest type | Value at various discount rates (million $, 1990/91 pr) 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|---|
| 95,000 | TDD+TMD | 289.96 | 205.74 | 155.53 | 111.74 | 93.59 |

7.7.1.2 <u>Alternative strategy I</u>: Here the assumption is that due to energy conservation effects, only 13290 MW of capacity is likely to come up in the Singrauli region by 2010. Further all new capacity will operate totally on washed coal. These would have an impact on both emission and costs as detailed in Tables 7.33 through 7.35. Environmental costs related to coal mining are the same as in the BAU strategy.

**Table 7.33.** Relating to TSP emissions from power plants (1990-91 prices)

| | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| 1. Levelized annual costs (cents/kWh) | 0.035 | 0.042 | 0.05 | 0.062 | 0.071 |
| 2. Costs/unit TSP removed (cents/kg) | 0.018 | 0.022 | 0.026 | 0.032 | 0.037 |
| 3. Total environmental damage ('000 $) (2010) | 5.7 | 6.8 | 8.0 | 10.0 | 11.0 |

**Table 7.34.** Relating to SOx emissions from power plants (1990-91 prices)

| | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| 1. Levelized annual costs (cents/kWh) | 2.6 | 2.6 | 2.7 | 2.8 | 2.9 |
| 2. Costs/unit SOx removed (cents/kg) | 45.49 | 46.43 | 47.48 | 49.19 | 50.41 |
| 3. Total environmental damage (million $) (2010) | 23 | 24 | 24 | 25 | 26 |

**Table 7.35.** Relating to NOx emissions from power plants (1990-91 prices)

| | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| 1. Levelized annual costs (cents/kWh) | 0.76 | 0.77 | 0.78 | 0.8 | 0.8 |
| 2. Costs/unit NOx removed (cents/kg) | 14.89 | 15.1 | 15.33 | 15.72 | 16.0 |
| 3. Total environmental damage (million $) (2010) | 11 | 11 | 11 | 11 | 12 |

7.7.1.3 Alternative strategy II: Both the costs and the total environmental demage from from TSP, NOx and SOx emissions from thermal power plants remains the same as in the BAU strategy.

7.7.1.4 Combination strategy: Costs and total environmental damage from TSP, $NO_x$ and $SO_x$ emissions from thermal power stations remain as in alternative strategy I.

7.7.2 Delhi

As mentioned in Chapter 4, the three major polluting sectors in Delhi are power, transport and industry. While, it has been assumed that industrial growth in Delhi would be frozen more or less at present levels, the growing sectors of this region are essentially the transportation sector and power generation. An additional installed capacity of 210 MW is proposed in this region at an annualised cost (net of fuel) of $311 million.

BAU (Power)
The impacts valued for the city of Delhi from emissions from power plants planned for the city to the year 2010. Tables 7.36 through 7.38 summarize the monetary values for TSP, $NO_x$ and $SO_x$ using the same approach and consumption as before.

**Table 7.36.** Relating to TSP emissions from power plants (1990-91 prices)

| | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| 1. Levelized annual costs (cents/kWh) | 0.033 | 0.04 | 0.047 | 0.059 | 0.067 |
| 2. Cost/unit TSP removed (cents/kg) | 0.16 | 0.19 | 0.23 | 0.28 | 0.32 |
| 3. Total environmental damage (thousand$) (1990-2010) | 3.70 | 4.43 | 5.23 | 6.56 | 7.5 |

**Table 7.37.** Relating to $SO_x$ emissions from power plants (1990-91 prices)

| | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| 1. Levelized annual costs (cents/kWh) | 1.98 | 2.03 | 2.09 | 2.18 | 2.24 |
| 2. Cost/unit SOx removed ($/kg) | 3.57 | 3.66 | 3.76 | 3.92 | 4.04 |
| 3. Total environmental damage (million $) (1990-2010) | 12.3 | 12.6 | 13.0 | 13.5 | 13.9 |

**Table 7.38.** Relating to $NO_x$ emissions from power plants (1990-91 prices)

| | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| 1. Levelized annual costs (cents/kWh) | 0.57 | 0.58 | 0.59 | 0.61 | 0.62 |
| 2 Cost/unit NOx removed ($/kg) | 1.14 | 1.16 | 1.18 | 1.22 | 1.25 |
| 3. Total environmental damage (million $,1990-2010) | 5.6 | 5.7 | 5.8 | 6.0 | 6.1 |

Alternative strategy I (Power)

For this case we consider the capacity expansion of 210 MW to occur using wash coal as input. The details are found in Tables 7.39 through 7.41.

**Table 7.39.** Relating to TSP emission from power plants (1990-91 prices)

| | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| 1. Levelised annual costs(cents/kWh) | 0.034 | 0.041 | 0.048 | 0.060 | 0.069 |
| 2. Cost/unit TSP removed(cents/kg) | 0.18 | 0.21 | 0.25 | 0.31 | 0.36 |
| 3. Total environmental damage ('000 $)(1990-2010) | 4.58 | 5.49 | 6.49 | 8.13 | 9.3 |

**Table 7.40.** Relating to SOx emission from power plants (1990-91 prices)

| | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| 1. Levelised annual costs(cents/kWh) | 2.09 | 2.14 | 2.2 | 2.3 | 2.4 |
| 2. Cost/unit SOx removed ($/kg) | 4.0 | 4.08 | 4.19 | 4.37 | 4.49 |
| 3. Total environmental damage (million $)(1990-2010) | 16 | 16 | 16 | 16 | 16 |

**Table 7.41.** Relating to Nox emissions from power plants (1990-91 prices)

| | 3% | 5% | 7% | 10% | 12% |
|---|---|---|---|---|---|
| 1. Levelised annual costs(cents/kWh) | 0.6 | 0.61 | 0.62 | 0.64 | 0.65 |
| 2. Cost/unit NOx removed ($/kg) | 1.27 | 1.3 | 1.32 | 1.36 | 1.39 |
| 3. Total environmental damage (milion $) | 7.1 | 7.2 | 7.4 | 7.6 | 7.8 |

Alternative strategy II (Power)

All costs and estimates of environmental damage are the same as under the BAU scenario.

Combination strategy (Power)

All costs and estimates of environmental damage are the same as under alternative strategy II.

Transport sector (Delhi)

The rapid increase in vehicular population in Delhi, the heavy levels of congestion and increase in pollution have highlighted the need to have a mass rapid transport system for the city of Delhi. The economic viability of this option has already been established earlier in this chapter. If one was to assume that this mass rapid transport system would be fully functioning by 2009-10, then the annual reduction in emissions resulting from the displacement of a portion of the vehicular population is given in Table 7.42.

**Table 7.42.** Emission reduction -- Metro option (Delhi, 2010)

(tonnes per annum)

| | CO | HC | NOx | $SO_2$ | TSP |
|---|---|---|---|---|---|
| Total | 228117 | 119595 | 8157 | 905 | 4011 |

## Appendix 7.1

**Regional Break-up of Economic costs of Energy Supplies in 2009/10 (5% GDP growth case)**

| | BAU Strategy | Strategy I | Strategy II | Combination Strategy |
|---|---|---|---|---|
| A. Regional distribution of costs excluding natural gas pipelines, fuel imports and power shortages ($ million, 1990/91 prices | | | | |
| NR | 18952 | 12692 | 19768 | 13529 |
| WR | 34994 | 33768 | 35392 | 33929 |
| SR | 20649 | 19011 | 21168 | 20211 |
| ER | 18241 | 16446 | 18368 | 16561 |
| NER | 7488 | 7298 | 7535 | 7342 |
| AI | 100324 | 89215 | 102231 | 91572 |
| B. All India costs, including natural gas pipelines, fuel imports and power shortages ($ million, 1990/91 prices). | | | | |
| | 128421 | 101859 | 129418 | 102856 |

## Appendix 7.2

**Regional Break-up of Economic costs of Energy Supplies in 2009/10 (6% GDP growth case)**

| | BAU Strategy | Strategy I | Strategy II | Combination Strategy |
|---|---|---|---|---|
| A. Regional distribution of costs excluding natural gas pipelines, fuel imports and power shortages ($ million, 1990/91 prices | | | | |
| NR | 20678 | 15368 | 21495 | 16195 |
| WR | 37705 | 36381 | 38103 | 36235 |
| SR | 22354 | 22059 | 22873 | 22820 |
| ER | 19493 | 16192 | 19619 | 16312 |
| NER | 8144 | 7713 | 8191 | 7807 |
| AI | 108374 | 97713 | 110281 | 99369 |
| B. All India costs, including natural gas pipelines, fuel imports and power shortages ($ million, 1990/91 prices). | | | | |
| | 145538 | 116558 | 146541 | 117560 |

## Appendix 7.3

**Economic Costs of Electricity Supplies in 2009/10 (1990/91 US cents/kWh sales)***

| | BAU Strategy | Strategy I | Strategy II | Combination Strategy |
|---|---|---|---|---|
| A. Low GDP Growth Case | | | | |
| NR | 9.040 | 7.321 | 9.226 | 7.643 |
| WR | 8.434 | 7.366 | 8.602 | 7.534 |
| SR | 8.122 | 7.323 | 8.593 | 7.733 |
| ER | 8.821 | 8.325 | 8.915 | 8.455 |
| NER | 8.999 | 8.480 | 9.007 | 8.617 |
| AI | 8.647 | 7.556 | 8.816 | 7.807 |
| B. High GDP Growth Case | | | | |
| NR | 9.191 | 7.791 | 9.348 | 8.033 |
| WR | 8.579 | 7.472 | 8.715 | 7.610 |
| SR | 8.348 | 7.783 | 8.661 | 8.090 |
| ER | 8.995 | 8.238 | 9.067 | 8.381 |
| NER | 8.963 | 9.022 | 9.005 | 9.018 |
| AI | 8.804 | 7.815 | 8.940 | 8.028 |

* In comparison, the cost of electricity generated through windfarms and small hydropower installations is US cents 20 and 14 per kWh of sales respectively; and shortage costs are US cents 24 per kWh of sales.

CHAPTER

8

---

Overall assessment of the strategies

---

## 8.1 Multi-attribute assessment

Of the entire set of impacts described in Chapter 4, impacts that differ amongst strategies and have not been costed are the transport and the industrial sectors. Therefore, the multi-attribute assessment need only be conducted for these sectors. Since only air emissions have been quantified for these sectors, the assessment is limited to 'airsheds' for each of the regions.

The impacts are assessed by considering the emissions of the five major pollutants (TSP, $SO_2$, $NO_x$, CO and HC) in the three zones (Chapter 4). The first step is the amalgamation of the zones in the regions to arrive at 'damage equivalent' emissions for each pollutant by assigning weights of 0.5, 0.4 and 0.1 for zones 1, 2 and 3 respectively, based on their relative damage potential. The next step is the aggregation of the pollutants to arrive at the 'damage equivalent' emissions for air as a whole. This is done by assigning weights of 0.18, 0.45, 0.36, 0.005, 0.005 for TSP, $SO_2$, $NO_x$, CO and HC respectively, again based on their relative damage potential. In the absence of a critical level, the 'damage equivalent' emissions for each of the strategies in the year 2010 have been used as a basis for comparison with the BAU. Table 8.1 gives the 'damage equivalent' emissions in the year 2010 for each of the strategies.

**Table 8.1.** 'Damage equivalent' emissions in the year 2010 across strategies ('000 tonnes)

| | North | West | South | East | N East | Total |
|---|---|---|---|---|---|---|
| 5 % GDP growth rate | | | | | | |
| BAU | 2799 36 | 5729 21 | 4705 42 | 4872 33 | 108 74 | 18215 06 |
| Strategy I | 1860.45 | 3116 76 | 1812 99 | 1639.82 | 20.05 | 8450 07 |
| Strategy II | 2794 44 | 5726 61 | 4704 73 | 4871 49 | 108 39 | 18205 66 |
| Combination strategy | 1855 53 | 3114 16 | 1812 30 | 1638 98 | 19 70 | 8440 67 |
| 6 % GDP growth rate | | | | | | |
| BAU | 3880 85 | 7958.95 | 6356 62 | 7467 92 | 151.01 | 25815 35 |
| Strategy I | 2173.53 | 3503.78 | 1890.03 | 1891.75 | 27.31 | 9486.40 |
| Strategy II | 3875.92 | 7956 35 | 6355.93 | 7467.06 | 150.66 | 25805 92 |
| Combination strategy | 2168 60 | 3501.18 | 1889.34 | 1890.89 | 26.96 | 9476 97 |

As can be seen, both strategy I and strategy II have lower values than the BAU, with the combination strategy having the lowest 'damage equivalent' emissions. This result is also intuitively obvious, since both the strategies individually result in lower emissions than the BAU (strategy I is conservation based, resulting in relatively lower emissions than BAU; strategy II is essentially renewable energy based along with a small penetration of CNG in the transport sector, resulting in relatively lower emissions than BAU) and therefore, the combination of both sets of measures, results in a further reduction in emissions.

## 8.2 Ranking of the strategies

The economic analysis in Chapter 7 and the Multi-attribute assessment have clearly shown the combination strategy to be the best, in which both conservation measures and alternative energy sources are considered. A comparison of the results of the alternative strategies I and II with the BAU strategy also suggests the desirability of implementing such measures. However, as the alternative strategies I and II comprise mutually exclusive options, it is not possible to compare them directly. The purpose is only to investigate the desirability of developments in these directions.

## 8.3 Constraints and issues encountered in the application of the methodology

The methodology for this study takes a leap forward from traditional energy planning models in that it attempts to include environmental aspects in developing an 'optimal' strategy. However, environmental impacts are only partly generic, the impact depends not only on the effluents emitted, but also on the ambient environmental conditions, number of people exposed etc., i.e. it is extremely site-specific. Therefore, environmental aspects for a strategy in a region can only be captured after site-specific environmental evaluations have been conducted. This is an extensive task and can only be accomplished on identified sites. This poses a major constraint on the use of this methodology, for it can only be used for planning in the short and perhaps the medium term, but not for strategic analysis. This issue needs to be addressed, and is an area for future research.

8.3.1 Constraints on demand projections.

For each energy consuming sector, information on its energy use patterns and determinants of its energy demand was only partially available -- a feature which impelled frequent resort to making educated and informed guesses.

This is particularly true for the residential and agricultural sectors. As far as households are concerned, available data are gathered from field surveys. Most field surveys are only one time exercises and do not shed any light on the evolution of energy use patterns in any rural or urban community in the past. In the urban households in particular, where appliance ownership patterns have changed considerably in the past decade (a trend which is likely to continue in the foreseeable future), there is little information, if any, on the utilization of these appliances. Needless to say, differences in energy consumption patterns across various income/expenditure category households is documented even less. Likewise, little is known on the changes in population over various income/expenditure categories.

In the agriculture sector, energy end-use data are again not compiled systematically, and the use of norms based on sample surveys may not always be desirable -- but is perhaps the only option.

As far as the transportation sector is concerned, available data are aggregated to the extent that it is usually not possible to derive any meaningful information on inter-state and inter-regional movements of goods.

It was not possible to use elasticities of demand to project energy demand because of (1) the system of administered pricing in India, (2) the constrained demand and the lack of flexibility to respond to changes in prices/income, (3) income data is highly uncertain, and (4) a large part of energy is consumed by the Government or the public sector which tends to be unresponsive to price signals.

Under such circumstances using demand elasticities to project demand would not be a realistic exercise.

8.3.2 Constraints on supply projections

The main constraints on the supply side emerged from the long time frame of the exercise, and the lack of information on energy supply plans beyond the year 2000. For example, for the power sector, schemes for coal TPS, nuclear, hydro and GT/CCP, are fairly well known only until the year 2000. For

the period beyond 2000, extrapolations were made keeping in view the shares of various types of capacity in different regions.

Another major problem relating to power system expansion projections stemmed from the fact that only peak power and energy demand forecasts were available. Owing to the fact that the various conventional generation options (hydro, coal, TPS, GT/CCP, nclear) and RETs (windfarms and small hydro) are not exactly technically substitutable, the analysis of supply options would be better if a load duration curve (LDC) were available for the year 2009/10. In fact, even a three-step load duration curve will be significantly better than the peak power and energy demand forecasts used here. However, projecting LDCs entails intensive data requirements, including the sectoral LDCs at present and anticipated changes in them to 2010. Even if the present sectoral LDCs were available (through a representative sample field survey in each region), it would be difficult to project them as the existing power shortages (which are much higher than projected levels) distort them significantly. Moreover, an increase in electricity using equipment and appliances in the coming years will also influence the sectoral LDCs considerably.

Lack of detailed geological information on the various petroliferous basins resulted in the projections being based on average gas to oil ratios and expected discovery index, and indicative costs per metre of exploration and drilling. It is fully recognized that this is not the best way to project oil and gas supplies, especially since it does not capture the probabilistic nature of the discovery process at all. However, it was the only way to project supplies in the absence of more detailed basinal information.

In the case of coal supplies, reasonably firm plans were available until 1994/95. Beyond this, it was necessary to extrapolate based on an assumption that coal development efforts would be rationalized in line with the presently known reserves position.

The projections for biomass availability were even more difficult to undertake because wide variations existed in the estimates of biomass availability, particularly of firewood. In this case, the approach was to use average figures for yield/availability, collection efficiency, etc.

Similarly, because it was not possible to predict the quality of crudes that will be used in refineries, refinery yields of various fractions were based on normative data.

8.3.3 Prediction of changes in environmental quality

For reasons mentioned in section 8.3 coupled with a lack of data, permitted only a partial coverage of the environmental impacts. A major drawback is the absence of site-specific information. For example, forest land submerged by hydro projects was only available for 38% of the planned capacity up to the year 2000. It is also not possible to use averages since data available on forest submergence/MW capacity revealed a range of three orders of magnitude. Similarly, information on relevant water quality parameters for stretches of rivers where the siting of future thermal power plants has already been done was not available, thereby restricting the evaluation of water quality impacts. In fact a major constraint in predicting changes in environmental quality was the lack of baseline information available on the country from which energy-related changes could be measured. However, impacts are not always separable in causal factors, and as such it was difficult to categorically establish a cause-effect relationship between energy development and environmental impacts, for example, in the case of reduced soil fertility in the vicinity of coal mining projects.

8.3.4 Economic analysis

8.3.4.1 Valuing environmental impacts: The constraints on predicting impacts did, but naturally, limit the valuation exercise. The choice of techniques that were used were determined largely by the availability of data, the nature of impacts to be valued, and the limitations of time. In general, direct and indirect techniques may be employed to value the environment. Direct techniques, such as experimental techniques, or those that use a surrogate market, are used essentially to value environmental gain from environmental improvement programmes. However, all these techniques are highly information intensive, and require the collection and analysis of a large amount of data. Indirect techniques do not measure direct revealed preferences for the environmental good in question but seek, instead, to calculate a 'dose response' on impact relationship between pollution and some effect, for example, impact of air pollution on crops, health of people, etc., and then use some measure of preference to value that impact. These are second-best approaches to valuation and involve methods such as preventive expenditures, replacement costs, damage costs avoided, etc. This study has, as seen in Chapter 7, used indirect techniques to value environmental impacts. However,

there were a number of difficulties faced even in doing this limited exercise, arising essentially out of a lack of location specific information. For example, lack of detailed forest cover (density) information available for the sites affected by coal and hydro projects resulted in this important element being ignored in the costing exercise.

As discussed earlier, a critical input in using indirect valuation techniques for environmental costing is the identification of dose-response relationships. This would typically require very detailed data on ambient air concentrations and pollutant loading, as necessary information. However, to assess the damage potential would require the use of dispersion models and would need to be carried out at a much more micro level than the regions defined for this study would permit. However, even if this were possible, to establish a link between mortality or poor health or reduced crop yield, and pollution, would require a large data bank of these and other socio-economic variables. No such level of detailed information is available in the country -- although an attempt was made to overcome this problem, albeit to a limited extent by 'zoning' the regions.

Most of the above constraints have resulted in cost estimates which are believed to be essentially lower bound values on environmental damage caused by energy activities (the singular exception may be the deployment of FGDs for $SO_2$ control). This will serve more to build an awareness of environmental considerations rather than to definitely place a value on energy-related environmental damage.

8.3.4.2 Other aspects of the economic analysis: The economic analysis of the three strategies was based on an evaluation of the direct economic costs associated with each of the strategies for each sector and region. Some of the cost estimates were developed in efficiency terms using standard conventions. However, it was not possible to derive economic prices in various cases and normative costs (based on some average or expected values) have been used. For example, in the case of power plants or coal mining capacity, $/kW of installed capacity in the former case and $/tonne in the latter case have been assumed without considering the implications of actual site conditions on investment requirements. Likewise, only normative O&M costs for energy production/conversion and environmental control equipment have been considered. For capital costs for environmental control equipment (namely, ESP, FGD, SCR) one had to rely on international costs information (per installed capacity) found relevant to the Indian case.

In the absence of detailed information, the study estimated fuel transportation costs for example, from coal mines to a TPS unit in a region by treating each region as a single destination point. It is acknowledged that this may not have led to good estimates of fuel transport costs.

8.3.4.3 Multi-attribute assessment: The system for scoring environmental impacts is developed, based on a critical level in the region for the parameters in question. When one is dealing with concentrations (air quality, etc.), the ambient standards provide this level and the scoring system can readily be developed. However, when one is dealing with emissions (or effluents), this level is extremely difficult to define over a region, and therefore, an absolute scale cannot be constructed. This is a major limitation, since moving from emissions (or effluents) to concentrations over a region is an extensive task (amongst other things, extremely data and time intensive) and cannot be undertaken for a study of this kind. This is an area that needs future research, for a multi-attribute assessment can be useful in terms of evaluating environmental qualities specific to a particular region.

CHAPTER 9

# Conclusions and Recommendations

## 9.1 Institutional feasibility of implementing most desirable plan

While discussing the institutional feasibility of implementing the combination strategy, one needs to first identify those weaknesses which currently hinder the implementation of desirable plans. Some of the major weaknesses that underlie this area result from the separate treatment of energy and environmental issues in the planning process, even when they are in actual fact closely connected. These are as follows:

(1) Energy planning seldom takes into account environmental impacts, largely because there is a lack of appreciation and skills within the energy sector on the precise nature of environmental impacts both in physical and economic terms. Consequently, energy planners often treat the preparation of environmental impact assessment reports as a ritual and an unavoidable nuisance at best and do not look at the wider implications of energy decisions on the ecology, natural resource base and environmental quality of a specific region.

(2) The Ministry of Environment and Forests, which is the nodal point for environmental clearance of energy related projects is not fully involved in the assessment of energy demands and formulation of supply options. Nor is this Ministry conscious of the economic implications of shortages in energy supply or the gestation periods of energy projects. Consequently, sharp differences in priorities and perceptions exist between the energy related ministries on the one hand and the Ministry of Environment and Forests on the other. Even though environmental control organisations in several states of India are still not very effective and strong in their functioning, the same perceptions are evident in these organisations at the state level as well.

Consequently, the environmental protection and control authorities in the country generally do not look at economic trade-offs and options, but generally treat environmental quality as a matter of absolute purity.

(3) Environmental effects and implications are looked at purely on a project to project basis, and not in terms of broad strategies and directions and aggregate effects. This problem arises largely because the country does not have an integrated energy policy, and, essentially, plans are put together on the basis of specific fuel and energy types with little assessment of fuel switching possibilities and substitutes either on the demand side or on the supply side. Consequently, strategies which would strengthen environmental protection have not been looked at in aggregate terms, in the absence of which projects are considered individually purely on the basis of their respective technical, financial and institutional feasibility without regard to their aggregate effects on the environment. Current project impacts are assessed at the local level in most cases and rarely, if at all, at the global level, as for instance, in the case of emissions of carbon dioxide and other greenhouse gases (GHGs). Quite understandably GHG emissions are not a matter of major concern in India at present, and if at all this subject is to acquire importance in the future, it would be only on the basis of international agreements that might allow for financing of additional costs and technology transfers for addressing the problem of GHG emissions.

It is evident that in order to implement the energy conservation and renewable energy options (combination strategy), priority would have to be provided to the following programmes and projects.

### 9.1.1 Energy conservation

Energy conservation efforts have thus far had to contend with irrational pricing of energy as exemplified by the heavy subsidies provided to irrigation pumping using electricity in the agricultural sector, as well as a lack of private sector and public participation in energy conservation programmes. The success of energy conservation in the future would depend on appropriate pricing of energy as well as public participation. For this purpose the setting up of a nodal organisation for energy conservation as recommended in the

mid '80s by the Advisory Board on Energy would be an essential first step. Such an organisation would necessarily have to be outside the Government but supported by the Government, so that it has credibility and clout in official terms, but without the encumberances of government procedures and processes. Such an organisation could then act as a focal point for catalysing industry, the public and the media in evolving national strategies and plans for energy conservation. It could also then lay down specific standards in consultation with the Bureau of Industrial Standards for a

9. large range of energy using equipment and appliances.

Specific programmes for each of the sectors are as follows.

9.1.1.1 Transport: Environmentally desirable options in the transport sector that need to be pursued during the 1990s and the first decade of the 21st century are listed below. None of these would be easy to implement with existing organisational and institutional arrangements. Hence a brief discussion is presented on institutional changes that are essential to realise these options.

1. Highway construction and maintenance: The economic analysis from Chapter 7 clearly shows that improved highway construction and maintenance would have significant benefits in terms of energy efficiency, alongwith other benefits like reduced pollution, reduced maintenance costs, etc. Given that the current arrangement for undertaking this activity is essentially through departments of the central and state governments, not only do improvements appear unlikely, but the prospect of mobilising additional financing seems bleak. Typical government budgetary procedures not only have inbuilt delays and lags but are also rigid in terms of expenditures that could be incurred within a certain budgetary period. Hence, it is common to find materials for road construction lying by the highway for long periods of time without mobilisation of other inputs which would make construction or repair possible. Improvements in this sphere of activity can come about if market forces were to create incentives for appropriate design, construction and upkeep of road networks. The involvement of the private sector and the introduction of payment for services by road users would bring about a major improvement in the condition of roads in the country and would also be able to harness the private sector for mobilising finances with a greater degree of flexibility.

As a workable plan of action, the Government should, in

the first instance, throw open the highways on which the highest density of traffic is found today by involving the private sector on a contract basis. Regulatory mechanisms could be built in to ensure that monopoly profits are not obtained by those operating and maintaining these systems. On the basis of experience thus obtained, perhaps in the next phase three years later, a larger section of the road network in the country could similarly be handed over for private sector management and operation. On the basis of a phased plan of action the bulk of the road transport infrastructure in the country should be brought under the management of the private sector.

2. Investments in urban rapid transit and metro facilities: Several cities in India have reached a point where urban congestion and pollution cannot be contained without major innovations such as establishing rapid metro transport systems. An interesting case in point is the city of Delhi, which among the metropolitan areas of the country has a rapid rate of population growth, and by virtue of its geography, a very high level of per capita mileage in terms of urban transport. RITES has carried out a series of studies establishing the feasibility of an urban mass transit system, the most recent of which was completed in 1989. However, the Government has not been able to implement this project for want of institutional infrastructure in the city's local government and adequate finances for the massive investment required. Yet the benefits to society from an appropriate metro system would be substantial. The scale of funding required, namely US $ 1.4 billion can only be mobilised from external sources. A concept that needs to be explored is that of the build-operate-transfer (BOT) option. This option would not only ensure quick and efficient implementation of the project but also bring into existence management and operational expertise which is essential for maintaining the system, once established, at high levels of efficiency. The Government of India should seriously consider pursuing this possibility for the city of Delhi to start with and other cities subsequently, if the experience with Delhi is successful.

3. Shifting of transport from roadways to railways: The last 30 years have witnessed a decline in the share of rail transport vis-a-vis road transport in India. In order to reverse this trend, the service provided by the Indian

Railways would have to improve substantially, and major technological upgradation would have to be brought about in the infrastructure and operations of the railways. In order to identify strategies for achieving this, the railways would first have to prepare a detailed perspective plan, in which it would be essential to get expertise and inputs from outside the system. Perhaps this is a possible technical assistance project which the ADB might consider pursuing. In essence, improvements in the hardware and technology of rail transportation would have to cover track renewal and upgradation, modernisation of signaling facilities, and improved technologies for traction equipment and rolling stock. The Indian Railways, like several other nationalised railway systems in the world, have been going through a period of difficult financial constraints. At the same time the technology gap between the Indian Railways and other systems in the world has grown progressively, and efficiency levels have remained more or less stagnant. There are strong organisational and institutional factors behind this trend. In essence, despite the commercial nature of railway undertakings in India, their functioning remains bound by government rules and procedures, and financing decisions are taken on the basis of sanctions by Parliament. To convert railway operations into a dynamic activity, the entire structure of the Indian Railways would have to be granted greater autonomy. As a first step, it would be necessary to convert the zonal railways into separate public sector undertakings, with the Railway Board functioning as a holding company. This would allow much greater flexibility and speed of decision-making to attract funds from the market for specific railway projects and programmes. The perspective plan mentioned above would necessarily have to cover the strategies for raising finances and capital resources from outside the budgetary process of the Government. Also, tariff decisions would need to be taken out of the purview of government decision making and left in the hands of a regulatory commission that could ensure both efficiency and equity in such decisions. Additionally the handling and management of 'smalls' in freight movement should be privatised, so that a greater market orientation is introduced in this component of traffic. This would win over much of the freight moved from road to rail.

9.1.1.2 Industry: The industrial sector, consuming approximately 40% of the total commercial energy offers an enormous potential for energy conservation, with measures having pay

back periods of 3 to 5 years. Amongst other options, two prime areas for energy conservation are co-generation, steam generation, transmission and distribution systems and electrical motors. A study by USAID for co-generation covering two states, Maharashtra and Gujarat, identifies a potential of over 10,000 MW for large scale power generation alone (100 - 200 MW). This could replace a major portion of expansion needs envisaged by the state electricity boards. But for this to become a reality even to a small extent, PURPA-type legislation and adequate credit facilities for co-generation projects would be essential prerequisites.

However, performance of industry in energy conservation has not been very encouraging. Undoubtedly, the motivation for efficient use of energy comes from market forces and the priorities of financiers and financial institutions. There are two major reasons why energy conservation programmes in Indian industry have not achieved great success, and these are, (i) lack of information and specialised knowhow and (ii) difficulties in obtaining capital from the financial institutions for clearly focussed energy conservation programmes. Two innovations are essential in bringing about a higher level of energy efficiency in the industry sector, and these are:

(1) The setting up of a nodal organisation for energy conservation outside the government, but with the support of the government and industry, which may, over a period of time, promote similar organisations at the state level or even on a sectoral basis.

(2) Instituting a specific window in each of the major financial institutions to deal with energy conservation projects.

Given the attractive rates of return from energy conservation, it is somewhat surprising that financial institutions have not taken a more active role in promoting conservation activities in industry. This has been largely the result of a lack of technical knowledge and an ignorance of opportunities for productive investments dealing with energy conservation. The financial institutions would have to include this set of opportunities in their policies and priorities in the future. Based on the availability of finance, several consulting firms and technical groups are likely to come up to fill up the gap in terms of technical expertise. There would also then be a movement towards energy service companies who can provide a full package of inputs to bring about improvements in energy efficiency in

the industrial sector.

9.1.1.3 Domestic: Domestic sector energy uses present large opportunities for efficiency gains and environmental benefits because not only is this sector projected to grow very rapidly in the future, but the economic incentives for improvements exist in the form of a large population of energy using appliances, wherein a small improvement would have a large multiplier effect. One factor inhibiting the improvement of appliance efficiency in India is the quality of power supply which inevitably results in over-designing of motor units, compressors and other such devices. It would be necessary to tackle this problem through a set of carefully controlled demonstration projects, wherein installations for voltage stabilisation and frequency control are made on a somewhat centralised basis rather than by each individual consumer. The social benefits of such a project would be substantial.

The standardisation of appliances in India leaves much to be desired. Even within the constraints of poor quality power supply, standardisation can bring about significant energy gains if implemented in a determined manner. This would have to be done through a detailed study of major energy using appliances, starting, for instance, with domestic refrigerators the population of which is likely to grow to 45 million by the year 2010. Refrigerator efficiency enhancements include improvements in basic design of the cabinet itself, the insulation material used, the compressor and refrigeration system and several other features of a standard refrigerator. Once standards have been set and targets laid down, improvements would have to come through a coordinated approach involving all the industries that are responsible for the manufacture of these components. While the initiative for these may be taken by the government, the actual implementation of such a programme would have to be carried out by industries themselves as part of a coordinated programme and in response to incentives, punitive measures or disincentives that the government may build into its strategy.

9.1.1.4 Agriculture: What applies to the case of domestic refrigerators and other appliances also applies to agricultural pumpsets. Government policy in the past has
9. favoured pumpsets being manufactured in the small scale sector, as a result of which compromises in design and quality of manufacture were the rule rather then the exception. It would now be necessary to lay down efficiency

standards for different designs of pumpsets and ensure their compliances in manufacture with a set of incentives and disincentives. Also, since a large number of pumpsets are purchased through financing from the nationalised banks and other development agencies, these banks could be made partners in the enforcement of standards, by eliminating the financing of sub-standard devices.

.1.2 Renewable energy technologies

.1.2.1 Enhanced development and utilisation of renewable energy technologies: As seen from the analysis, wind power upto a certain percentage of the peak generating capacity can be viable and accepted by the system. It appears that in spite of all the constraints (discussed in Chapter 5) wind farm capacity additions of about 3000 MW is realisable by the year 2010. A certain percentage of capacity is expected to be installed by private industries which will wheel the energy generated to their plants. Measures here could include incentives in the form of tax benefits, etc. However, the major additions are expected to be either installed by the utility itself or by the private parties and intended for sale to the utility. Since the purchasing organisations, namely the state electricity boards are essentially monopsonies, legislation of the PURPA type would be essential not only to ensure adequate resources being allocated to this activity, but also to see that optimal choices are exercised in the location of wind power facilities on the basis of economic merit.

Small hydel capacity is also seen to be a viable option and a capacity of approximately 1500 MW is a realisable target till the year 2010. This capacity will be partly distributed amongst the grid connected and non-grid connected areas. The canal drop schemes which constitute a significant portion of the capacity and which have a relatively lower cost of generation are mostly distributed in grid connected areas. Although, the marginal costs of generation will be relatively higher for small hydel units other than canal drops in remote areas, it should be noted that the avoided cost of generation at such locations will also be higher.

Other economically viable technologies include biogas plants and solar cookers. Solar cookers dissemination programmes have been in existence for over a decade. In the rural areas they have not made much impact due to the inherent limitations of the technology mentioned above and

its cost. However, solar cookers have good potential in semi-urban and peri-urban areas where accessibility to fossil fuels is relatively less and where fuelwood is commercialised.

The optimal utilisation of renewable sources of energy would be dependent entirely on the development of a market with suitable response on both the demand and supply sides. While generally consumers would make rational decisions based on price and quality of renewable energy devices available in the market, on the supply side several existing distortions and restrictions would need to be removed urgently. The development of a renewable energy industry in India has been constrained by an over-centralised approach, which not only requires the approval of designs of devices for manufacture, but also permissions of various kinds to actually set up manufacturing. The system of subsidies further distorts the profile of the industry, whereby only a few manufacturers are able to reap the benefits of subsidies without strong incentives for competitive performance. Thus, not only is there inadequate improvement in designs and quality of manufactured products but also in after sales service and customer orientation. A complete delicensing and decontrol of the sector would be essential to bring about a large enough response in the evolution of a healthy market for renewable energy devices.

9.1.2.2 Reorientation of renewable energy R&D: The approach to research and development in renewable energy technologies requires major reorientation to bridge the gap between lab and land. Most of our work on renewables in the past has been concerned with theoretical research with little attempt to develop marketable products or devices. A correction of this trend requires not only an appropriate choice of institutions and organisations in which R&D should be promoted, but also a set of incentives and disincentives for product development and the involvement of industry in such efforts to ensure the rapid spread of appropriate technologies using renewables.

## 9.2 Measures on the overall energy system

### 9.2.1 Natural Gas

The flaring of natural gas in India is a criminal waste which would not be allowed in any other country of the world. The reason for this continuing waste is the cumbersome decision

making structure and "turf" battles between different ministries and departments of the Government of India. The problem could be circumvented by setting up an empowered committee at a high level that could take decisions on complex questions of natural gas utilisation for a variety of applications, but this would be a cumbersome method which is likely to be subjected to pressures of various kinds and, therefore, optimal decisions are unlikely to emerge. A far more effective approach would be to regulate gas prices at the wellhead and allow markets to function through private sector participation in all the downstream activities related to natural gas supply and utilisation.

Given the fact that natural gas production is likely to be completely absorbed through consumption in the business-as-usual scenario, it would be useful to explore options for import of natural gas over and above the level allowed for in this scenario, if necessary by pipeline from countries such as Bangladesh and Iran. At this stage India could carry out feasibility studies of existing import options. These studies could perhaps be financed by the ADB along with the provision of suitable technical assistance. Since international negotiations and agreements as well as mobilisation of investments in infrastructure are long gestation activities, it is not anticipated that imports of natural gas will materialise to any great extent in the near future, but this is entirely possible within the time horizon upto the year 2010. As such, these options need to be explored and assessed seriously in view of their environmental and economic benefits.

### 9.2.2 Oil

From the analysis, India's oil imports are increasing every year, and, even for the conservation strategy would need a level of 54 MT per annum in the year 2010. Therefore, It is essential to have a new hydrocarbons policy implemented under a new and different regime of relaxed controls and regulations in order to step-up indigenous production. The components of a new hydrocarbons policy would be,

1. An immediate increase in production without sacrificing the ultimate recovery of reserves already established.
2. Restructuring the hydrocarbons industry for achieving cost effectiveness in exploration, production and refining.

Immediate measures to be taken for increase in overall production of hydrocarbons would require an improvement in the reserves to production (R/P) ratio. In essence, thi

ratio which in various exercises carried out for the Eighth Five Year Plan is targetted at 16:1 in the terminal year of the Eighth Plan should be improved gradually to a level of 7:1. As it is, the R/P ratio in India is much higher than several other countries of the world. It should be possible even with existing reserves to increase production by around 10 million tonnes annually within the next 5 years. This would, however require a far more liberalised regime for investments and decision making and early mobilisation of resources to bring about such an outcome. Similarly, natural gas production can be increased to about 70 million cubic metres per day at the end of 5 years.

The achieving of higher productivity and efficiency in the hydrocarbons industry is dependent on major and far reaching organisational/institutional changes. The hydrocarbons industry must gradually move towards privatisation and reduced involvement of government in day-to-day decision making. For instance, under government rules, the finalisation of tenders can take up to two years, which no oil company in the world can afford.

The system of specific rounds for inviting foreign and private oil companies for exploration is outdated and cumbersome. Government must immediately announce a framework of policies for attracting foreign companies into oil exploration, and allow bids to be made regularly for specific areas which must be thrown open to the private sector and the international oil companies. Countries such as Malaysia and Indonesia which followed the rounds system earlier have given up this practice long ago.

Several small and marginal fields must be handed over to the private sector immediately for production from these locations on a contract basis. A number of private sector and joint sector companies may be allowed to enter the hydrocarbons sector by opening up exploration and production and also by converting ONGC into a public limited company with 10-15% equity holding by the public.

The state of technology in the hydrocarbons industry in India has lagged behind developments in other countries. A far more open approach has to be pursued for tying up of Indian oil companies with foreign companies for ensuring early improvements in hydrocarbons technology in the country.

9.2.2.1 Opening up refining to the private sector: Due to an increase in consumption of middle distillates our refinery configuration has become unbalanced, with the result that we have to import refined products at high cost. For reasons

cited in section 9.2.2 above, private sector participation including foreign oil companies is essential.

.3 Coal

The setting up of coal washeries is an option that needs to be vigorously pursued. This option is economically viable, having multiple benefits in the form of better plant performance, reduction in ash-handling equipment, improvement in ESP removal efficiencies, and a reduction in the transportation costs. The heat value of washery rejects can readily be exploited by combustion in an AFBC boiler located at the washery site for power generation.

Results show coal production and usage to rise over 500 MT in the year 2010. This would require a rapid expansion of the coal transportation and distribution system. In 1989/90, the railways carried 135 MT of coal which constituted 42% of the total freight transported by the railways. This capacity would need to be expanded along with other infrastructural aspects, such as ports, etc.

2.4 Power

The power sector, apart from problems of indigenisation of equipment, poor quality coal supply and restricted pricing powers, etc. is essentially overburdened in relation to its managerial capabilities and infrastructure. The industry, therefore, requires an inflow of superior managerial expertise, which can be achieved through the involvement of the private sector. This would also bring in larger financial resources for the electric utility industry. Imbalances in low investments for transmission and distribution facilities also need to be corrected early to ensure proper utilisation of generating capacity, and minimising T&D losses nationally.

The government has recently announced some specific steps for involvement of the private sector in power generation, but these are likely to have limited success. The private sector is unlikely to seek business opportunities in this sector, if it is tied down to the state electricity boards as its main customer. Unless an entire region is thrown open to the private sector for generation, transmission and distribution, private capital and enterprise are unlikely to enter this sector in a big way. Since the gap between electricity demand and installed capacity is growing, early steps are essential for attracting private capital into the power sector.

9.2.5 Rural energy sector

Three-fourths of the Indian population are in the rural areas and meeting their energy requirements is an enormous task. Traditionally rural people have depended on biofuels for their energy needs at a 'zero private cost'. However, increasing pressure on the environment due to various factors including rapid population growth has necessitated the need for finding cost effective and environmentally sustainable energy alternatives. Substitution of biofuels by more superior commercial fuels appears limited in the forseeable future, primarily due to to the low purchasing power of the rural population and relatively limited market penetration. Consequently, the focus needs to be on the following:

(1) Enhancement of energy supply options such as afforestation and wastelands development which are also environmentally sound.

(2) Dissemination of biomass based efficient technologies like biogas plants, briquetting, improved cookstoves, etc.

However, the implementation of rural energy programmes in the past has suffered from several limitations. These may be overcome by the following measures.

(1) Energy development strategies need to be integrated with the overall development planning at a decentralised level so that the development priorities of the people are taken into account.

(2) The dissemination of any technology should not be done in isolation but as part of an energy system. Therefore, one would need to look at energy supplies and demands at a localised level. This warrants a 'bottom-up' approach.

(3) The research and development activities in appropriate technologies should be location-specific. Also the training needs required for successful implementation of the energy programmes should be carefully identified and the training imparted.

To summarise, it is clear that energy and environmental planning has to be closely integrated in the country if human welfare is to be maximised and resources used in the energy sector are to be directed at optimal choices. The first pre-requisite for this would be the setting up of an organisation for energy strategy formulation and planning at the national level. It would perhaps not be desirable to think in terms of an official body to perform this function, but a loosely constituted set-up consisting of senior representatives from government departments, research institutions and the major

energy supply organisations could serve as an effective body for evolving and monitoring national energy plans and their implementation. The Ministry of Environment and Forests would have to be an important and effective part of this set up. The secretariat facilities and analytical work for this loosely structured body should preferably be outside the government, so that adequate academic, research and intellectual inputs could be effectively mobilised to provide direction and shape to future energy policy and plans. The organisation could be given the title of National Energy Policy Committee, and its work should be visible and debated openly on a continuing basis.

The problems of energy pricing, environmental protection and local effects of energy decisions are so closely interrelated, that they require comprehensive treatment at a decentralised level throughout the country. It is clear that an overcentralised approach to energy planning taking into account environmental considerations would not only be cumbersome and tardy, but also likely to ignore optimality on a local and regional basis. It would, therefore, be essential to bring into existence regulatory commissions at the regional level which are empowered to arrive at pricing decisions as well as environmental actions related to the establishment of energy projects. These commissions should deal with energy across the board ranging from the coal mines to power plants, refinery facilities and large distribution facilities which may have environmental implications. Pricing issues are critically important in the implementation of environmental protection plans. It has been seen, for instance, that the establishment of coal washing facilities in the country, even when economically justified to the fullest measure, have not been implemented because of differences between the coal and power industries on sharing of the costs involved. The regulatory commission proposed should be empowered to come up with decisions on such issues, which would be binding on the parties concerned.

At a micro level the integration of energy and environmental planning can be achieved most effectively through a coordinated training approach, whereby energy professionals are appraised of environmental implications and issues while those dealing with environmental protection and standards are trained in the economics of environmental protection, wherein the trade-offs involved in control regimes and measures are the guiding principles as against treating standards as absolute on the basis of technical considerations.

**Chapter 1**


Advisory Board on Energy (1985), Towards the Perspective on Demand and Supply in India in the Year 2004/05, New Delhi.

Central Pollution Control Board (1991), Ambient Air Quality Status of some cities/towns in India, New Delhi.

Central Water Commission (1988), Water Resources of India, New Delhi.

Champion, H.G and Seth, S.K. (1968), A Revised Survey of Forest Types of India, Manager of Publications, New Delhi.

Chaphekar, S (1991), A Running Problem, The Hindu Survey of the Environment.

Government of India (1952), The National Forest Policy of India, Manager of Publications, New Delhi.

Government of India (1987a), Mangrooves in India : Status Report, Ministry of Environment and Forests, New Delhi.

Government of India (1987b), Biosphere Reserves, Ministry of Environment and Forests, New Delhi.

Government of India (1988a), Forest Survey of India, Dehradun.

Government of India (1988b), National Forest Policy 1988, Ministry of Environment and Forests, New Delhi.

Government of India (1988), Perspective Planning for Commercial Energy, Planning Commission, New Delhi.

Government of India (1989a), India's Forests 1987, Ministry of Environment and Forests, New Delhi.

Government of India (1989b), Wetlands, Mangrooves and Biosphere Reserves, Ministry of Environment and Forests, New Delhi.

Government of India (1990a), Land Use Statistics, 1986-87 and 1987-88, Ministry of Agriculture, New Delhi. (Memiographed)

Government of India (1990b), The State of Forest Report 1989, Forest Survey of India, Dehradun.

Government of India (1990c), Developing India's Wastelands, Ministry of Environment and Forests, New Delhi.

Government of India (1990d), Wetlands of India - A Directory, Ministry of Environment and Forests, New Delhi.

World Resources Institute (1991), World Resources 1990-1991, World Resources Institute, Washington D.C.

**Chapter 2**


Centre for Monitoring Indian Economy (1980-1990) Annual Issues: Basic Statistics relating to the Indian Economy, Vol 1&2.

Dharmarajan, K. (1988), Urban Growth and Household Energy, Energy Policy Issues, Vol. 4 (1988), Tata Energy Research Institute, pp 48-64, New Delhi.

Engineering Consultants (Pvt.) Limited (ENCON), 1986, Report on Estimation of Total Road Transport, Freight and Passenger Movement in India, submitted to Department of Surface Transport, GOI, New Delhi.

Fertilizer Association of India (1990), Fertilizer Statistics (1989-90), New Delhi.

Government of India (1965), Report of the Energy Survey of India Committee, Government of India, New Delhi.

Government of India (1979), Report of the Working Group on Energy Policy, Planning Commission, New Delhi.

Government of India (1980), Planning Commission, Report of the National Transport Policy Committee, pp 44, New Delhi.

Government of India (1985), Planning Commission, Seventh Five Year Plan, 1985-90, Volume I, pp 11-12, New Delhi.

Government of India (1987), Report on Energy Audit of Paper Industry, Bureau of Industrial Costs and Prices, Ministry of Industry, New Delhi.

Government of India (1987), Report on Energy Audit of Cement Industry, Bureau of Industrial Costs and Prices, Ministry of Industry, New Delhi.

Government of India (1988), Report on Energy Audit of Aluminium Industry, Bureau of Industrial Costs and Prices, Ministry of Industry, New Delhi.

Government of India (1988), Planning Commission, Report of the Steering Committee on Perspective Planning for Transport Development, New Delhi.

Government of India (1988), Report of the National Commission on Urbanization, Volume II, pp 94-95, New Delhi.

Government of India (1989), Report on Energy Audit of Integrated Steel Plants, Bureau of Industrial Costs and Prices, Ministry of Industry, New Delhi.

Government of India (1989), Report on Energy Audit of Fertilizer Industry, Bureau of Industrial Costs and Prices, Ministry of Industry, New Delhi.

Government of India (1990), Working Group on Demand and Supply Projections and Improvement of Agricultural Statistics for the Formulation of the VIII Five Year Plan, Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi.

Government of India (1991), Registrar General & Census Commissioner, India 1991, Series-1, Provisional population totals, paper-1, New Delhi.

Karnataka Energy Consultants (KEC), Energy Conservation in Agricultural Pumpsets, Monitoring and Evaluation Report.

Mittal, V.K., Mittal, J.P., Dhawan, K.C. (1985), Research Digest on Energy Requirements in Agricultural Sector, ICAR, New Delhi.

National Council of Applied Economic Research (1978), Household Income and its Disposition, Volume 2, New Delhi.

National Council of Applied Economic Research (1985), Household Income and its Disposition - A Micro Level Study, New Delhi.

National Council of Applied Economic Research (1985), Domestic Fuel Survey With Special Reference to Kerosene, New Delhi.

National Sample Survey Organisation (1986), Sarvekshana, Vol.9, No.3 (January).

Rao, K.L. (1979) India's Water Wealth, Orient Longman Ltd., New Delhi.

Tata Energy Research Institute (1988), Report on Urban Household Energy Survey, submitted to the Advisory Board on Energy, New Delhi.

Tata Energy Research Institute (1989), TERI's Energy Data Directory and Yearbook, New Delhi.

Tata Energy Research Institute (1990), Study of India's Commercial Energy Demand, submitted to the World Bank, New Delhi.

Tata Energy Research Institute (1990), Mathematical Model for Demand Forecast of Coal, New Delhi.

Tata Energy Research Institute (1991), MS/HSD Sales through Retail in Northern Region, New Delhi.

**Chapter 3**

Government of India (1980), Report of the Committee on Power, Planning Commission, New Delhi.

Government of India (1988), Perspective Planning for Commercial Energy, Planning Commission, New Delhi.

Government of India (1989a), Report of the Working Group on Coal, Planning Commission, New Delhi.

Government of India (1989b), Report of the Working Group on Petroleum, Planning Commission, New Delhi.

Government of India (1989c), Report of the Working Group on Power, Planning Commission, New Delhi.

World Bank (1990), The Stauts of Liquified Natural Gas Worldwide, Industry and Energy Department Working Paper, Energy Series Paper No.25, Washington, D.C.

**Chapter 4**

Allan J.C. and Barnes D.F. (1985), The Causes of Deforestation in Developing Countries. Annals of the Association of American Geographers 75(2) : 163-184.

Centre for Science and Environment (1985), State of India's Environment, New Delhi.

Food and Agricultural Organization (1980), 1979 Production Yearbook, Volume 33, Rome.

Food and Agricultural Organization/United Nations Environment Programme (1982a), Tropical Forest Resources Assessment Project - Forest Resources of Tropical Africa, Rome.

Food and Agricultural Organization/United Nations Environment Programme (1982b), Tropical Forest Resources Assessment Project - Forest Resources of Tropical Asia, Rome.

Government of India (1988), Perspective Planning for Commercial Energy, Planning Commission, New Delhi.

Government of India (1989), Report of the Working Group on Coal. Planning Commission, New Delhi.

Mathur A. (1989a), Environmental Impacts of Thermal Power Generation. Reading Material for the Workshop on Energy and Environment, 4-5 August, 1989, organized by Tata Energy Research Institute, New Delhi.

Mathur H.B. (1989b), Impacts of Surface Transport on Air Environment of Major Metropolitan Cities of India. Workshop on Energy and Environment for inputs into the National Conservation Strategy, organized by Tata Energy Research Institute, New Delhi.

Meyers N. (1980), Conservation of Tropical Moist Forests. Report prepared for the Committee on Research Priorities on Tropical Biology of the National Research Council, Washington D.C., National Academy of Sciences.

National Capital Region Planning Board (1987), Draft Regional Plan 2001 - National Capital Region, Ministry of Urban Development.

Ramachandran T.V., Lalit B.Y and Mishra V.C. (1990), Modifications in Natural Radioactive Content of Soil Samples around Thermal Power Stations in India, Indian Journal of Environmental Health, 32(1) : 13-19.

Thakre R. and Thergaonkar V.P. (1985), Studies on Physio-Chemical Characteristics of Soil amended with Flyash and their Effect on Germination of Wheat, Cotton and Tomato. Proceedings of the National Symposium on Evaluation of the Environment.

**Chapter 6**

Government of India (1986), Beneficiation of Non-Coking Coal for use in Thermal Power Stations, Ministry of Energy, New Delhi.

Government of India (1988), Report on Trial of Beneficiated Non-Coking Coal from Nandan Washery at Satpura Thermal Power Station, prepared by the National Productivity Council, New Delhi.

Meiers P, and Thukral K. (1990), Analyzing Environmental Trade-offs in Power Sector Planning: A Case Study of the Western Indian Region, presented at the 12th International Conference of the IAEE, New Delhi.

Suri L.R. and Natarajan (1952), paper presented at the Indo-German Conference on Power Plant Operations, New Delhi.

**Chapter 7**

Baasel W.D. (1985). Economic Methods for Multi-pollutant Analysis, Marcel Dekker Inc. N.Y.

CMIE (1991), Basic Statistics Relating to the Indian Economy.

Das T.M. (1980), Value of a Forest, Indian Science Congress.

EPRI (1988), Modern Power Systems, July.

Lal J.B. (1990), Economic Value of India's Forest Stock, Van Vigyan, Vol 28, No.3, p.63-72).

Planning Commission (1988), Perspective Planning & Policy for Commercial Energy, Government of India, New Delhi.

Scharer & Haug (1986) quoted in CDA/ERL, Acid Rain and Photochemical Oxidants : Control Policies in the European community - A Decision Framework, p 1X.56.

Schulz W. and E. Schulz (1991), The Fed. Republic of Germany, in J.P Barde and D.W. Pearce (ed), Valuing the Environment, Earthscan Publication Ltd., London, 1991, p.38-40.

Shen T.T. (1980), The Environmental Impact of Conventional Fossil Fuel Sources in L. Theodore and A.J. Buonicore (eds), Energy and the Environment Interactions. Vol. I Part A, CRC Press Bocaraton.

Tata Energy Research Institute (1991), Report on Integrated Energy Pricing.